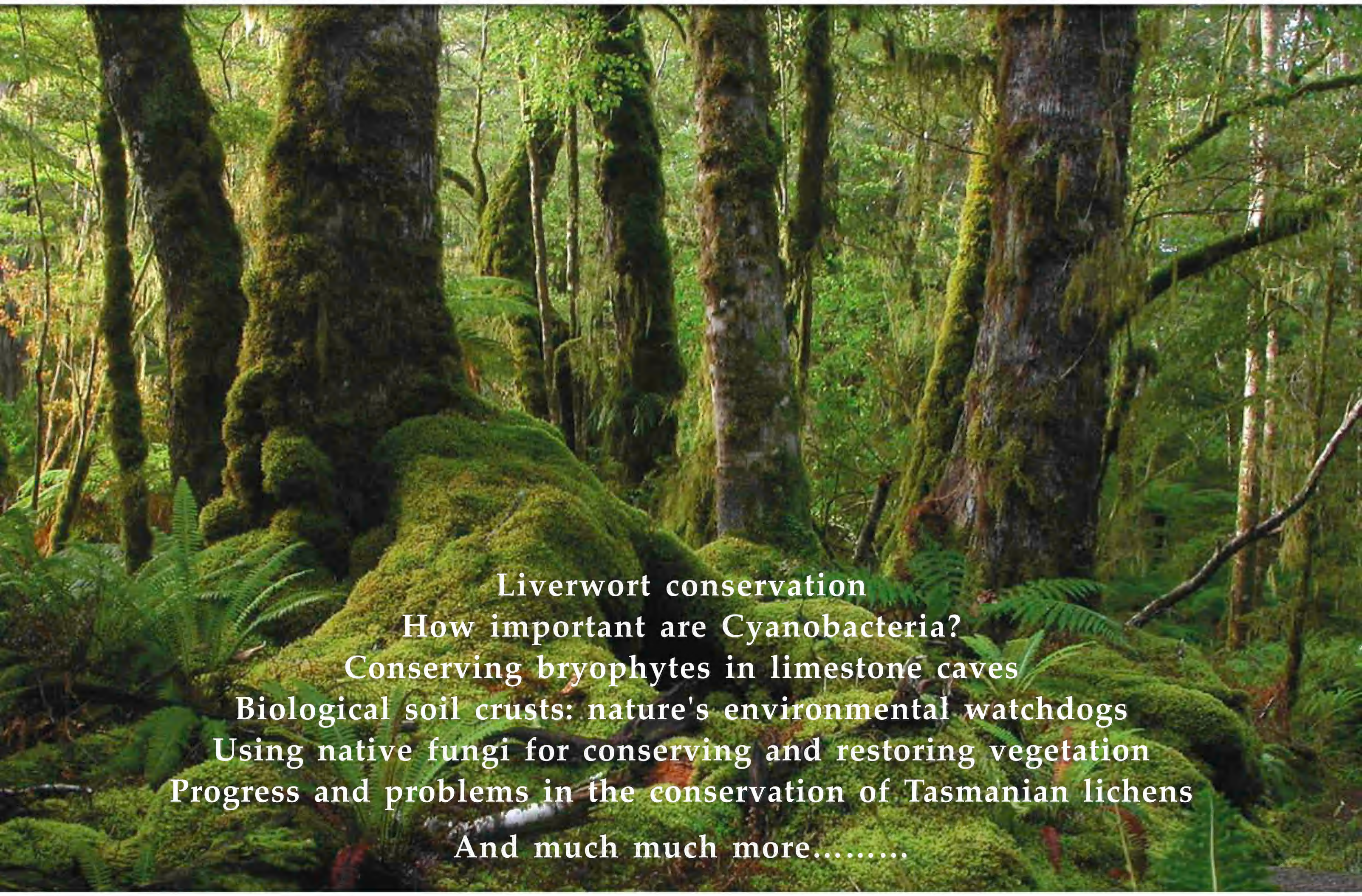
Australasian Plant Conservation

BULLETIN OF THE AUSTRALIAN NETWORK FOR PLANT CONSERVATION

VOLUME 14 NUMBER 1 • JUNE - AUGUST 2005



Liverwort conservation
How important are Cyanobacteria?
Conserving bryophytes in limestone caves
Biological soil crusts: nature's environmental watchdogs
Using native fungi for conserving and restoring vegetation
Progress and problems in the conservation of Tasmanian lichens
And much much more.........

Special Theme: THE FORGOTTEN FLORA REMEMBERED

This Issue

Forgotten flora remembered 2
Using native fungi for conserving and restoring biodiverse vegetation in the Australian wheatbelt 3
Surveys of fungi in South Australia 6
Fungi in conservation and management at the catchment and bioregion level 8
Fungi conservation in Italy: a case study from Tuscany and Sicily 10
Long-term prospects for conservation of *Cladia ferdinandii* in the Aldinga Scrub Conservation Park, South Australia 12
Progress and problems in the conservation of Tasmanian lichens 13
Variation in Cool Temperate Rainforest lichens of Victoria: implications for conservation 16
Rare and endangered liverworts: A new area of conservation in New Zealand 17
Bryophyte reproductive ecology and conservation 20
Managing bryophyte diversity on limestone karst systems 22
Biological soil crusts: nature's environmental watchdogs 24
Cyanobacteria: Life in Environments under Stress 26

Regular Features

Resource Kit Review 28
Research roundup 29
Information Resources and Useful Websites 30
ANPC Workshops 31
Conferences and workshops 32

Australasian Plant Conservation Editor

Tom May. Thanks also to Tricia Hogbin, Sally Stephens and Helena Mills.

Layout & Graphic Design

Siobhan Duffy

Australasian Plant Conservation is produced by the ANPC Inc. with assistance from the Australian National Botanic Gardens. Support for this special edition was also provided by the Royal Botanic Gardens Melbourne.

Australasian Plant Conservation is printed on recycled paper.
ISSN 1039-6500

ANPC National Office

GPO Box 1777, Canberra, ACT 2601,
Australia
Ph: (02) 6250 9509
Fax: (02) 6250 9528
Email: anpc@deh.gov.au
Web: http://www.anbg.gov.au/anpc

ANPC Plant Conservation Email List

To subscribe, unsubscribe or post a message send a request to anpc@deh.gov.au

National Office Staff

Sally Stephens and Pamela Strickland

Volunteers

Jan Hastings, Laura Vallee, and Richard Bomford.

ANPC Committee

President

Judy West

Vice President

Bob Makinson

Treasurer

Vacant

Secretary

Tricia Hogbin

Committee Members

John Arnott, Trevor Christensen, Roger Good, Paul Janssens, Tom May, Helena Mills, Leonie Monks, Rosemary Purdie, Andrew Smith

New Zealand Plant Conservation Network

President Mike Oates
Secretary John Sawyer
PO Box 16-102 Wellington, New Zealand.
Email: info@nzpcn.org.nz
Web site: www.nzpcn.org.nz

ANPC Inc. Mission Statement

"To promote and develop plant conservation in Australia"

Contributing to *Australasian Plant Conservation*

Australasian Plant Conservation is a forum for information exchange for all those involved in plant conservation: please use it to share your work with others. Articles, information snippets, details of new publications or research, and diary dates are welcome. **The deadline forsubmissions for the September - November 2005 issue is Monday 3rd October 2005.**

Authors are encouraged to submit images with articles or information. Please submit images as clear prints, slides, drawings, or in electronic format. Electronic images need to be at least 300 dpi resolution, submitted in at least the size that they are to be published, in tif, jpg or gif format.

Please send typed or handwritten articles, no more that 2 A4 pages (or 1100 words), by fax, mail, email, or on diskette. If sending by email, please send as a MS Word (2000 compatible) or rich text format attachment to: anpc@deh.gov.au.

Opinions expressed in this publication are those of the authors and are not necessarily those of the ANPC or its sponsors. Material presented in *Australasian Plant Conservation* may be copied for personal use or published for educational purposes, provided that any extracts are fully acknowledged. Where any material is credited to and/or copyright to another source, please contact the original source for permission to reprint.

Front cover: (left to right) Cyanobacterial soil crust (dark cover over soil) with liverworts and mosses. Photo: S. Williams; Foliose lichen. Photo: Teresa Lebel; The fungus *Hygrocybe lewellinae*. Photo: Ian McCann; (main) bryophyte carpet in Cool Temperate Rainforest. Photo: Anneke Veenstra-Quah (reproduced with permission from Forgotten Flora resource kit).
Cover design: Siobhan Duffy.
Printed by: Pirion, Canberra.

President's report

Judy West

Centre for Plant Biodiversity Research
CSIRO Plant Industry

Effective plant conservation happens through interactions between various contributors, including land managers and landholders, community groups, government agencies, industry, researchers and on-ground practitioners. Through hosting a national conference on aspects of plant conservation and strategic directions every couple of years, ANPC aims to bring together these groups with different skill sets, providing the venue for effective exchange of information and network development.

The 2005 ANPC National Conference, **Plant Conservation: The Challenges of Change**, is to be held in Adelaide from 26th September to 1st October, hosted jointly with the South Australian Department for Environment and Heritage and the Botanic Gardens of Adelaide. Four symposium themes have been recognised to tease out the challenges we are facing in plant conservation into the future –

1. Extreme policy changes
2. Urban ecology
3. Using revegetation to achieve ecological outcomes
4. Indigenous interests in conservation

The conference program includes two days of scientific program, a field day and two days of workshops, several of which have arisen from feedback provided by participants in various workshops during the past year.

The program is shaping up with some stimulating papers. REGISTER NOW to play your part and contribute ideas for a strong presence and good conservation outcomes.

See www.plevin.com.au/ANPC2005

ANPC's workshops on *Translocation of Threatened Plants* are proving to be popular and appear to be approaching the subject with the right balance of theory and practical applications to provide the participants with real implementation strategies. As mentioned in my report in the last issue of APC, the NSW Environmental Trust has supported ANPC to run three of these workshops in regional areas of NSW. Two of these have already taken place, with one in Queanbeyan (May 18) and another recently held in Newcastle (July 28) with over 40 participants, many of whom were environmental consultants of each, in addition to staff of state government agencies, local councils, land managers and representatives of NGOs. This particular workshop also attracted some media attention. The third translocation workshop for NSW will be held in Coffs Harbour on August 30, and another will be run in association with the National Conference in Adelaide on October 1 – see http://www.plevin.com.au/ANPC2005/workshops.htm.

We also mentioned earlier the workshops on approaches & techniques for *Rehabilitation and Management of Disturbed Native Vegetation.* The first of these was held in Armidale 19-20 July with 103 participants from as far north as Queensland and south to Sydney, and representing a wide range of constituencies – community groups, environmental consultants, government agencies, CMAs, local government and those from NGOs, or with weeds interest or landholders. The feedback on the workshop has been positive with indication that focusing on the knowledge and skills required to undertake ecological rehabilitation and management of disturbed native vegetation is filling a void for the practitioner.

Another two rehabilitation workshops will be held in New South Wales:

- Wagga Wagga: 14-15 September
- Dubbo: 25-26 October

The last of these will be followed by a Grass Identification techniques workshop in Dubbo on 27 October.

Details for all three workshops are on the ANPC website - http://www.anbg.gov.au/anpc/wshop-NSWrehab-2005.html, including registration form.

This edition of APC on "Conservation of Cryptogams" includes several very interesting articles raising awareness of the role different cryptogams play in ecosystem functioning, much of which has been taken for granted in the past, and remains poorly understood. The ANPC greatly appreciates sponsorship towards this issue of *Australasian Plant Conservation* from the Royal Botanic Gardens, Melbourne.

ANPC National Conference - Reminder

Adelaide, 26th September to 1st October 2005

For details, see page 32

Forgotten flora remembered

Tom May

Royal Botanic Gardens Melbourne, Private Bag 2000, South Yarra, Victoria 3141. Email: tom.may@rbg.vic.gov.au

Cryptogams (fungi, lichens, mosses, liverworts, algae and cyanobacteria) have, with some justification, been thought of as the 'forgotten flora'. Cryptogams are unrelated phylogenetically, but are united by their mostly small and cryptic nature, and have been much less studied taxonomically and ecologically than the so called 'higher plants'. However, the contributions to this special issue show that efforts to conserve cryptogams are gaining momentum.

There is also growing awareness of the ecological importance of cryptogams, especially through interactions with other biota. Vital roles that cryptogams play in ecosystem functioning mean that they cannot be ignored in conservation, even if the focus is on more obvious biota (such as trees) rather than the cryptogams themselves. **Bougher** provides a startling statistic that in the wheatbelt of Western Australia less than one percent of beneficial macrofungi are present in revegetation. He provides specific advice on assisting the introduction of native fungi in revegetation.

For fungi, a number of current projects are directed at compiling distribution and ecological information on which to base assessment of conservation status. **Catcheside** and **Catcheside** discuss some of the challenges of surveying for macrofungi in South Australia. They show that single visits to a site may only reveal a small proportion of the species actually present. **Syme** and **May** discuss the preparation of a report on fungi for a regional natural resource management organisation in the south coast area of Western Australia, and suggest that it is important for fungi to be included in reports and management plans for all such regions across Australia. **Perini** and **Venturella** provide an interesting perspective on the conservation of fungi in Italy, where redlists are now being compiled on a national and regional basis.

In South Australia, even though the rare lichen *Cladia ferdinandii* is present in a Conservation Park, **Elix** raises concerns about the effect of adjacent housing developments on its survival. For conservation of Tasmanian lichens, **Kantvilas** documents considerable progress, but also problems in incorporating lichens into general conservation strategies. It is often assumed that cryptogams are 'dragged along' by conservation efforts targeted at vascular plants (or genera habitats). However, Kantvilas presents a sobering statistic that only a third of the Tasmanian lichens formally listed on conservation schedules are found in conservation reserves. **Morley** and **Gibson** demonstrate that for lichen diversity in Victorian temperate rainforests the successional stage may be more important than the patch size, and thus even small stands may host a high diversity of lichens.

Hypocreopsis sp. 'Nyora', the only fungus currently listed under the Victorian *Flora and Fauna Guarantee Act*. Photo: Tom May

There has been a tendency to shy away from assessment of the conservation status of cryptogam groups in a comprehensive fashion, often due to perceived difficulties in applying strict IUCN categories. **von Konrat** and co-workers report on recent progress in the conservation of New Zealand liverworts, including an update to the list of threatened species. They have taken a pragmatic approach to aspects such as the definition of individuals.

Listing alone will not ensure conservation. The next step is to understand biology and ecology, to enable effective management. **Gibson** provides an overview of bryophyte reproductive ecology, and shows that there are some unique factors to be taken into account in conserving bryophytes, such as skewed sex ratios. For limestone karst systems **Downing** and **Oldfield** present specific management recommendations aimed at maintaining bryophyte diversity, and limiting the introduction of species exotic to the habitat.

Diverse cryptogams make up the biotic soil crusts that are significant, albeit cryptic, components of many Australian landscapes. **Eldridge** summarises several recent studies demonstrating links between crusts and the health of woodland ecosystems. The critical relevance of understanding cryptogams in the general management of ecosystems is highlighted by the role of crusts in enhancing germination of native plants, while restricting the germination of weeds. Cyanobacteria are another important component of soil crusts and **Williams** and **Skinner** describe positive ecological roles such as nitrogen fixation. They suggest management practices that can assist the conservation of soil crusts, such as de-stocking during drought.

The issue concludes with the regular roundup of recent research and other resources, with a focus on the cryptogamic theme. It is encouraging to see the review of the 'Forgotten Flora' resources, a valuable aid for secondary school teachers, and also useful in raising the profile of cryptogams such as in national park visitor centres. Hopefully the ‘Forgotten’ part of the title will become outmoded before too long.

The papers in this special issue certainly indicate a healthy level of interest in conserving cryptogams in Australia, and there is no doubt additional information on the conservation of groups not covered in this issue, such as microfungi (May, 2005) and marine and freshwater algae. There are also some very significant initiatives in New Zealand, such as documented for liverworts by von Konrat *et al*. (this issue), but also for groups such as fungi (Buchanan & May, 2003). To build on the evident need and enthusiasm for cryptogam conservation, the ANPC will be hosting an Email list on the topic (see box).

References

Buchanan, PK. & May, TW. (2003). Conservation of New Zealand and Australian Fungi. *New Zealand Journal of Botany* 41: 407-421.

May, T. (2005). Looking after the bad guys: the conservation of pathogenic fungi. *Australasian Plant Conservation* 13(4): 20-21.

ANPC Cryptogam Conservation Email List

In addition to the current ANPC Plant Conservation Email list, ANPC is commencing a Cryptogam Conservation Email list. The aim is to foster and improve communication among those with an interest in crytogam conservation in Australasia and to provide an opportunity to share and exchange ideas.

- New literature about cryptogam conservation
- Links to interesting websites about cryptogam conservation
- Ideas about how to best conserve cryptogams
- Discussion on different approaches to conserving cryptogams
- Summaries of new student projects related to cryptogam conservation

Please send any items of interest to Tom May (Royal Botanic Gardens Melbourne, tom.may@rbg.vic.gov.au), who will collate them for a Bulletin that will be distributed to the Email list on an irregular basis as material become available. Notifications of workshops and conferences can be sent out immediately as required.

If you would like to subscribe to the Email list, please send a request to anpc@deh.gov.au with the message: Subscribe ANPC Cryptogam Conservation. It would assist if you could add your address (or at least your phone number) in the body of the email (for checking if email address does not work in future).

Using native fungi for conserving and restoring biodiverse vegetation in the Australian wheatbelt

Neale L. Bougher

Western Australian Herbarium, Department of Conservation and Land Management, Locked Bag 104, Bentley Delivery Centre, WA 6983, Australia. Email: NealeB@calm.wa.gov.au

There are many more species of fungi than plants in Australia but knowledge is limited about their distribution, biodiversity, ecological roles and propagation. This may have limited recognition of the role of fungi in conservation and management of Australia’s biodiversity. Many hundreds of species of native fungi occur in, and support the long-term health of, natural vegetation in Australia’s wheatbelt. Several hundred fungi species can occur within relatively undisturbed small patches (a few hectares) of remnant woodland, but the abundance and diversity of fungi varies depending on extent of disturbance. Major conservation issues include management of some potentially rare and endangered fungi unique to wheatbelt remnants and also of fungi in remnants dependant on locally extinct small mammals for their dispersal. A major issue for the long-term health of wheatbelt landscapes is that these fungi take a very long time, (if ever) to self-establish in revegetation or restored bushland on wheatbelt farmland. Fungi need assisting back to help restore the biodiversity and long-term health of both revegetated areas and existing areas of degraded natural vegetation.

In Australia’s wheatbelt, various strategies are being set in place to help nurture profitable and environmentally sustainable wheatbelt landscapes for the long-term. This includes strategic placement in catchments of vegetation for commercial products, together with retained and new plantings of biodiverse native vegetation. A typical practice for re-establishing biodiverse native vegetation in farming catchments is to source local seed from natural remnants to stock new plantings on farms. However, usually little consideration is given to the prospect that sustainable diverse revegetation may not be achieved by returning the plants the myriad without other organisms that comprise the diversity and ecological functioning of natural vegetation. This prospect is heightened in many parts of the wheatbelt with small, highly scattered, degraded or diminishing remnants. Populations of organisms within remnants may be declining towards a point where the remnants may no longer provide a source of genetic material for natural regeneration or human-assisted revegetation.

Endoptychum wariatodes, *a truffle-like fungus from woodland. Photo: Tom May*

Fungi play pivotal roles in natural vegetation

Vegetation in Australia's wheatbelt occurs mostly on soils of low nutrient availability for plants. In remnants, plant productivity and maintenance of soil quality depend largely on the activity of soil organisms, including fungi. Most fungi produce extensive networks of microscopic threads (mycelia). These effectively form the feeding and growing body of the fungi. The fruit bodies of macrofungi (such as mushrooms, toadstools, puffballs, truffles) are the easily visible signs fungi are present. However, below ground it is the vast networks of mycelium which allow comprehensive exploration and colonization of precious resource patches in soil. Fungi have a significant role in decomposition of dead organic matter and beneficial symbiotic (mycorrhizal) relationships with most plants. Mycelia also bind the soil and contribute to soil structure and erosion control. In addition, fungi provide food for some large animals such as woylies and potoroos and for many invertebrates and microbes. In the case of underground fruiting (truffle) fungi, there is a three-way interdependence between fungi, their mycorrhizal partner plants and native mammals that feed on fungi.

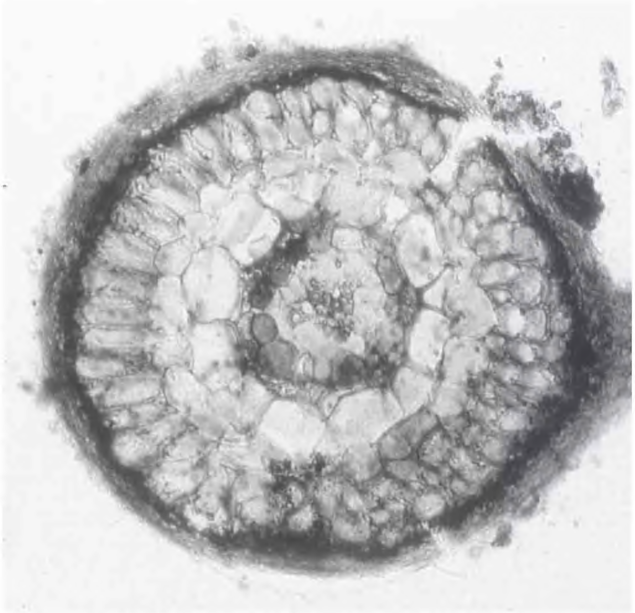
Mycorrhizal fungi are one of the major contributing factors explaining why native trees in natural vegetation in the wheatbelt grow well without fertilizer applications. In wheatbelt remnants, mycorrhizal fungi are associated with most woody plant species, e.g. *Eucalyptus*, *Acacia*, *Allocasuarina* and *Gastrolobium*. Fungal networks act like an extra root system with the capacity for greater exploration of soil than by roots alone. The fungi deliver soil nutrients directly to the plants and receive sugars in return.

Do native fungi re-establish in revegetation?

In contrast to their diversity and pivotal functional roles in natural vegetation, few or no native fungi of natural vegetation occur on cropland. Fungal populations struggle to re-establish naturally when trees, shrubs and other vegetation found in nearby remnant vegetation are planted on former farmland. Less than 1% of beneficial native larger fungi found in remnant bushland have returned to revegetated areas on wheatbelt farmland even after 20 years. When woody plants are revegetated, most native fungi are unable to colonize and thrive on the altered soil environment of former farmland. Potential implications of reduced or eliminated fungal biodiversity in such situations include a decline in the decomposition and nutrient cycling processes undertaken by the fungi and ineffective re-introduction of fungus-eating animals. The health of plants dependant on symbiotic mycorrhizal fungi may deteriorate.

Assisting native fungi in revegetation

Fungi need to be, and can be, assisted back into revegetated areas in order to enhance biodiversity below and above ground and to help re-establish the natural processes that have contributed to long-term sustainability of natural vegetation in the past. Techniques for restoring native fungi into revegetation on Australian wheatbelt farms at minimal cost have been developed recently. They are outlined in FungiBank (see box). The techniques can be used for new plantings, existing revegetation or degraded remnants. There is a diverse choice of native fungi available to select from for putting back into target areas. One key to success is to have some knowledge about local fungi so as to be able to select, source and restore appropriate fungi and avoid wasted effort – just as one would select appropriate plant seeds.



Cross section of mycorrhizal root showing outer mantle of fungal hyphae. Photo: Chris Dunk

Successful re-establishment of native fungi is not easily measured and there should be no set target number of fungi for re-introduction. The target should be to establish healthy, self-sustaining revegetation and remnants for the long-term with a high diversity of native fungi, plants and other organisms. It is logical to aim for restoring as many fungi in revegetation as possible. However, restoring any appropriate fungal species is a more practical goal and worth the effort as they may gradually improve the soil from one that is unsuitable to one that may encourage other native fungi to transfer later from nurtured remnants nearby.

Australia's natural reservoirs of native fungi are rapidly depleting as remnants in regions such as the wheatbelt diminish in number, size and quality. It is a race against time to use our remaining native fungi with minimal disturbance of remnant natural vegetation.

Literature

Bougher, NL. & Tommerup, IC. (2003). Restoration of Australia's native fungi for improved commercial environmental forestry, farm revegetation and sustainability in the Australian wheatbelt region. *Microbiology Australia* 24: 38-39.

Bougher, NL., Tommerup IC. & Bolsenbroek SQ. (2003). How can we improve farm revegetation, remnant vegetation and sustainability using native fungi? *Workshop proceedings. Kondinin Western Australia*.

Tommerup IC. & Bougher NL. (2000). The role of ectomycorrhizal fungi in nutrient cycling in temperate Australian woodlands. In: RJ. Hobbs & CJ. Yates (Eds.). *Temperate Eucalypt Woodlands in Australia: Biology, Conservation, Management and Restoration.* Surrey Beatty & Sons, Chipping Norton, pp 190-224.

Spore print from mushroom, on paper. This is one way of collecting spores for use in inoculating seedlings.
Photo: Teresa Lebel

INTRODUCING NATIVE FUNGI INTO REVEGETATION

Information from **FUNGIBANK** WEB SITE (www.fungibank.csiro.au)

- There are no commercially available sources of native fungi for revegetation.
- The best way to introduce fungi to revegetation is to inoculate seedlings with fungal spores.
- Fungal spores can be added to soil before or after seed germination.
- It is best to obtain fungi from your local area as they are likely to be best suited to your revegetation. This also helps to maintain local gene pools.
- Spores from mushrooms can be gathered by doing spore prints on soil.
- The powdery spore mass from puffballs can be added directly to soil.
- See **FUNGIBANK** for detailed protocols about restoring native fungi into revegetation or degraded sites.
- **DO NOT COLLECT SOIL** from native vegetation (this can cause irreversible damage to the existing vegetation and risks transfer of pathogens).

Surveys of fungi in South Australia

Pam Catcheside[1] *and David Catcheside*[2]

[1]*State Herbarium of South Australia. Email: Catcheside.Pam@saugov.sa.gov.au.* [2]*School of Biological Sciences, Flinders University*

Since 1997 we have been monitoring larger fungi in parks and reserves in South Australia. We record the presence of their spore-bearing structures, the fruit bodies. These may be produced throughout the year but the main fruiting period is autumn and early winter. In South Australia the season starts with the first significant rains, tails off when it becomes cold and dry, and may be as short as six weeks or extend for sixteen. In that time we travel thousands of kilometres in pursuit of fungi. We have begun to evaluate the conservation status of fungal taxa, especially of rare species and are continuing to identify fungal 'hotspots' — sites with unusually diverse mycoflora.

Fungi survey methods

In a single visit it is not possible to ascertain total numbers of fungal taxa at a site. Fungal fruiting depends on environmental factors and thus is irregular. Most fruit bodies decay quickly, and many are cryptic and easily missed when present in low numbers. Therefore sites need to be monitored frequently and over many years. Tofts and Orton (1999) recorded agaric and bolete fungi from a pine forest in Scotland over 21 years and found that the total species number observed increased more or less linearly throughout that period, with no convincing sign that the rate of growth of the species list was declining. Most of our survey sites are in parks and reserves in the South-east, Murraylands, Northern and Southern Lofty Ranges, Kangaroo Island, Flinders Ranges and Eyre Peninsula. Small sites are surveyed in a day or less; a large, rich area such as Flinders Chase, Kangaroo Island takes a week. Our collecting schedule must be flexible to take advantage of significant local rains, to which we are often alerted by park rangers.

We follow standard methods of collecting, describing and preserving fruit bodies (Bougher & Syme 1998, Grey & Grey 2005). At each site species are listed and data such as precise location, soil type, habit and vegetation are recorded, and specimens collected. At all sites we cover the same terrain as on previous visits. In large parks we may have up to 20 survey 'points', fixed by GPS determined latitude and longitude and chosen as representative of local biogeographic zones or because they are amongst our known hotspots. Survey 'points' vary in area but are never less than 100 m ^{2}.

New fungi found every year at all sites

For each park a species list is compiled, the total number of species for the year counted and the cumulative species total estimated. For example, in the first year 30 species may

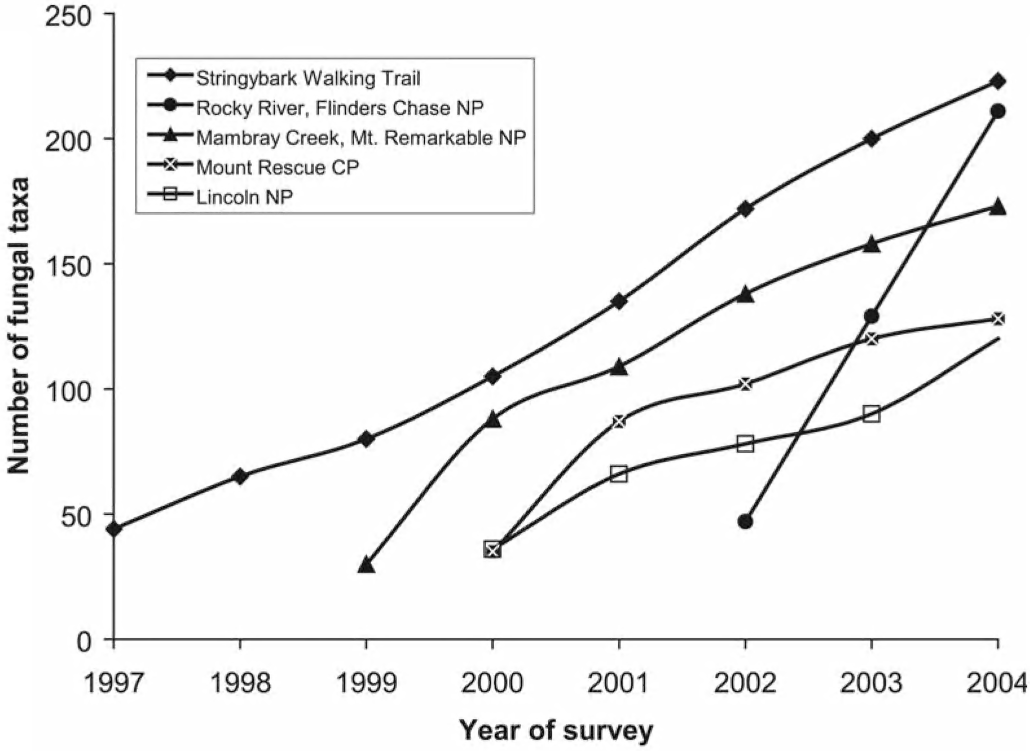


Figure 1: Accumulation curves over time for the detection of species at five representative sites from more than 90 survey sites for South Australian macrofungi.

be recorded, in the second only 15, but 8 of those may not have been recorded the first year; so the cumulative species total is 38. The number of species at all sites surveyed has continued to increase year by year with little indication that the rate of detection of additional species is declining at any site (Fig. 1). We have surveyed and compiled fungal lists for over 90 parks. In some we have recorded as few as one species, in others more than 200. In total we have made over 10,000 records of more than 450 fungal species including several yet to be described, and made over 2200 collections now deposited in the State Herbarium of South Australia.

Amongst the richest sites in South Australia are Flinders Chase National Park on Kangaroo Island, where we have found approximately 210 species in only three years of surveying in the Rocky River area alone, and Stringybark Walking Trail in Deep Creek CP at the tip of Fleurieu Peninsula, where more than 220 species were found over eight years. Both sites are relatively undisturbed and are remnants of once extensive vegetation. Our Rocky River site covers an area of approximately 10,000 ha whereas Stringybark Walking Trail is only 18 ha, so the number of taxa recorded is remarkable for such a small site. The accumulation curve for Stringybark has been rising steadily at approximately 25 species per year and does not appear to be levelling off.

Of the three other sites for which species accumulation curves are plotted (Fig. 1), Mambray Creek in Mount Remarkable National Park, part of the Southern Flinders Ranges, is in a steep gorge with sides covered with *Eucalyptus* spp. and *Callitris glaucophylla*. The sandy soil of Mount Rescue in the Murraylands supports *Banksia* heath and mallee eucalypt. Much of the vegetation of Lincoln National Park on the tip of Eyre Peninsula is coastal mallee. At these sites the species accumulation curves continue to increase, but irregularities in monitoring make it difficult to ascertain whether they are levelling off. Mambray Creek was surveyed only once in 2003 and 2004 but twice in the two previous years; Mount Rescue was surveyed late in the 2004 season.

Rare fungi and fungi hotspots in South Australia

From our results and from data collected by Grgurinovic & Simpson (2001), we can suggest conservation status and probable rarity of some fungal taxa. The term 'rare' is used here to denote any species for which there is only one SA collection in the State Herbarium prior to 1995 and no more than two of our collections since 1998. Additional listed sightings, where collections were not made, are also taken into account. Species we consider to be rare include *Amanita rosea*, Mauve Splitting Cap *Hygrocybe lewellinae*, a truffle *Endoptychum melanosporum*, an underground Amanita *Torrendia arenaria* (Fig. 2), Round Morel *Morchella esculenta*, and Beaton's Club *Underwoodia beatonii.*

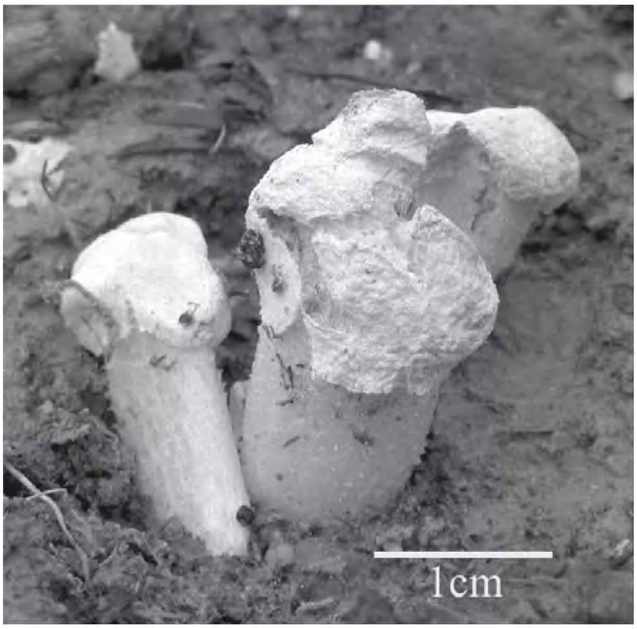


Figure 2: Torrendia arenaria*, a rare fungus in South Australia. Photo: David Catcheside.*

As data accumulate it also becomes possible to identify fungal 'hotspots'. However, at no site is it yet possible to predict total numbers of fungal taxa. There are many variables that affect the fungi recorded: numbers and timing of visits each year, variations in temperature and rainfall, as well as the irregularity of fungal fruiting where a species abundant in one year may not be seen again for many years. It is thus essential to monitor ecosystems over many years to determine the true extent of their fungal biodiversity and thus to optimise the management of their communities.

Acknowledgements

The project is partly funded by a Wildlife Conservation Fund grant.

References

Bougher, NL. and Syme, K. (1998). *Fungi of Southern Australia*. University of Western Australia Press.

Grey, P. & Grey, E. (2005). *Fungi Down Under*. Fungimap, Royal Botanic Gardens Melbourne.

Grgurinovic, CA. & Simpson JA. (2001). Conservation status of the known Agaricales, Boletales, Cantharellales, Lycoperdales, Phallales and Russulales of South Australia. *Fungal Diversity* 8: 97-127.

May, TW. (1997). Fungi. In: GAM. Scott, TJ. Entwisle, TW. May & GN. Stevens (Eds.). *A Conservation Overview of Australian Non-marine Lichens, Bryophytes, Algae and Fungi*. Environment Australia, Canberra.

Tofts, RJ. & Orton, PD. (1998). The species accumulation curve for agarics and boleti from a Caledonian Pinewood. *The Mycologist*. 12: 98-102.

Fungi in conservation and management at the catchment and bioregion level

Katrina Syme[1] *& Tom May*[2]

[1]*RMB 1020 South Coast Hwy, Denmark, WA 6333. Email: syme@westnet.com.au* [2]*Royal Botanic Gardens, Melbourne, Private Bag 2000, South Yarra, Victoria, 3141*

Introduction

A national conservation overview for Australian fungi (and other non-marine cryptogams) was prepared by Scott *et al*. (1997). For fungi, apart from some advances in taxonomic knowledge and about a dozen species listed on state conservation schedules, most recommendations in the overview have not yet filtered down as targets at state, regional and local levels.

Across Australia, fifty-seven regions have been identified for the purposes of addressing natural resource management and sustainable agriculture priorities. Most regions are based on catchments or bioregions. Each region has at least one body responsible for managing and protecting their region's natural resources (see www.nrm.gov.au). These regional bodies are significant for the delivery of funding for research and management across all tenures. Each region is required to develop, in consultation with their communities, a strategy and investment plan that addresses all values across that region. The strategies are to be based on sound technical input published in background papers.

The South Coast Regional Initiative Planning Team (SCRIPT) is the community based regional body for most of the south coast of WA (see www.script.asn.au). The SCRIPT Region covers an area of more than 5.4 million hectares. It includes the catchments of all the southerly-flowing rivers from Walpole in the west to beyond Cape Arid in the east. The Region is renowned for its spectacular landscapes, including tall forest areas in the west, the southern coastline and all of the mountain peaks in the south of W.A. It has extremely high levels of biodiversity, with more than 20% of the State's floristic diversity within the Region.

This article reports on the experience of the senior author in preparing a background technical report on fungi for the South Coast Regional Strategy for Natural Resource Management (Syme 2004). This Regional Strategy appears to be the first in Australia to include fungi and recommend further investment on their conservation and management. The purposes of the report were to (1) demonstrate the current state of knowledge of fungi, (2) list conservation threats to fungi, (3) discuss the importance of fungi to healthy ecosystems and (4) recommend key management actions to improve the understanding, knowledge and conservation of fungi.

Collecting fungi data

It was important to know how many and which fungi occur in the SCRIPT region. There were several sources of data on this. Collections (mainly of macrofungi) were held in various herbaria in Australia but also in a number of overseas institutions. Some information on herbarium collections is not readily available to the public and some herbaria charge a fee per record. For collections held in Australian Herbaria, Australia's Virtual Herbarium (www.rbg.vic.gov.au/avh/) provided a very useful way of determining which species occurred in the south coast, although the website must be queried on a species by

Boletellus ananiceps (left)*, and* Lactarius clarkeae (middle)*, mycorrhizal fungi;* Ramaria *sp., (right) one of numerous fungi from the south coast region yet to be identified to species. Photos: Katrina Syme.*

species basis. For collections held overseas, many of the visiting mycologists who had made collections were known to the author and information was provided electronically. Otherwise, tracking down these collections would have been rather difficult.

The Australian Fungimap organisation (www.rbg.vic.gov.au/fungimap) has available accurately mapped records sent in by volunteer recorders, but this is currently restricted to 100 target species. Lists of fungi made by the senior author during workshops and forays held in the south coast region provided the greatest number of records.

Records required considerable sorting to bring together synonyms under the current name. Names were updated from the Interactive Catalogue of Australian fungi website (http://www.rbg.vic.gov.au/research_and_conservation/fungi/cat).

The taxonomy of fungi lags decades behind that of plants, with numerous species yet to be described and no comprehensive guide for Australian fungi. One problem with the data collected was the large number of unnamed collections. From the SCRIPT region, a total of 2,857 fungi collections were unidentified to species level and 229 were not even identified to genus. In the genus *Amanita* alone, 272 records were not identified to species.

Data available for each of the six subregions varied considerably and this will be typical of most regions in Australia. The senior author resides in the Albany subregion, which has been the subject of three protracted studies and numerous fungi conferences and workshops, resulting in the largest number of fungi records. Some 2,464 individual collections or records were compiled for this subregion, including 373 named species. In contrast, Pallinup North Stirling had only 19 species recorded and the Fitzgerald Biosphere, world-renowned for its plant species richness, had only 69 species, most of which were listed during a two-day workshop.

A total of 504 named species of fungi were recorded from the SCRIPT region. Although some of the unidentified fungi will prove to be duplicates assigned different epithets, numerous additional species are expected. It is clear that a high diversity of fungi can be expected within the one catchment or bioregion.

Threats and ecological roles

The most important threat to macrofungi identified for the region is loss of habitat from clearing for agriculture and mining, exacerbated by climate change, disease, weed invasion and inappropriate fire regimes. Other problems for fungi are the lack of funding for research, the few trained mycologists to carry out research, at the widespread ignorance of the ecological importance of fungi.

Across the continent fungi are crucial to the viability and stability of Australia's nutrient-poor soils and to revegetation efforts. In some regions there may be linkages between fungi and other organisms that are specific to the region or relate to high profile plants or animals. It is useful to highlight these connections. For example, the SCRIPT region contains the only known population of Australia's most endangered mammal, Gilbert's Potoroo, whose diet almost exclusively consists of truffle-like fungi and which has a gut specifically designed to digest them. Like their rat kangaroo cousins the Woylies, they play an important role in conditioning the soil and spreading spores of beneficial fungi. Fungi are also mycorrhizal partners to rare native orchids which occur in the region, such as the Underground Orchid, *Rhizanthella gardneri*.

Recommendations

Actions recommended in the report included:

- Collect and document occurrence and frequency of macrofungi species in different plant communities and climatic zones across the region.
- Produce simple pictorial field guides to local fungi to assist land managers and help stimulate interest in the wider community.
- Produce project kits for schools as well as ensure that fungi information is published in newsletters and online.
- Identify rare/threatened fungi and investigate the life history of some key fungi in order to develop general recommendations for management of fungi.

Conclusion

Because regional strategies and investment plans are important for day-to-day on-ground delivery of conservation, getting fungi integrated into these plans is vitally important. Within each state it might be worthwhile as a first step to focus efforts on selected regions and develop some general principles about integration of fungi into vegetation and habitat management, which could then be applied to all regions. It would be ideal if information could be freely shared among different regions.

In preparing reports on fungi for natural resource management, it will be difficult to find people with the necessary knowledge. A few individuals and specialist groups (such as Fungimap and local fungal studies groups) have accumulated considerable knowledge of fungi at a local level. Such non-government groups will be able to provide valuable information towards management and policy documents, but it is neither realistic nor fair to expect them to entirely cover what should be done by local, state and federal governments, particularly without the provision of adequate funding.

References

Scott, GAM., Entwisle, TJ., May, TW. & Stevens, GN. (Eds.) (1997). *A conservation overview of Australian non-marine lichens, bryophytes, algae and fungi.* Environment Australia, Canberra.

Syme, K. (2004). Fungi information for the South Coast Regional Natural Resource Management Strategy. Report commissioned by the South Coast Regional Initiative Planning Team (SCRIPT).

Fungi conservation in Italy: a case study from Tuscany and Sicily

Claudia Perini[1] *& Giuseppe Venturella*[2]

[1]*Department of Environmental Science, University of Siena, vi P.A. Mattioli 4, I-53100 Siena, Italy.*

[2]*Department of Botany, University of Palermo, Via Archirafi 38, I-90123 Palermo, Italy.*

Information on fungi and their conservation status and distribution provides the foundation for informed decisions about preserving biodiversity at local to global levels. According to Courtecuisse (2001), the most important tool for fungal conservation is the conservation of their habitats, such as through *in situ* conservation on mycological reserves (Senn-Irlet, 1998) or ecological corridors (Alexander & Watling, 1987).

In the last 30 years there has been considerable mycological research through the whole Italian territory, both in the long-established field of taxonomy, but also in ecology, increasingly in areas of relevance to conservation, such as the effect of forest management on fungal communities (with a focus on edible mushrooms). Recent efforts that have advanced conservation of Italian macrofungi also include preparation of checklists and redlists and mapping projects.

In 1997 the Working Group for Mycology of the Italian Botanical Society published a preliminary red-list (Venturella *et al.*, 1997). Twenty three macrofungi were assigned to category K (Poorly Known) of the IUCN scheme (actually Data Deficient), in view of the fact that it was not possible to assign them with confidence to any of the definite IUCN categories. The almost complete lack of information on past distribution meant that comparison against present records was difficult.

In the following years efforts were concentrated in mapping macrofungi to create a first Italian check-list as a base for protection and conservation. A first regional inventory was published in Tuscany, which listed more than 1000 species of macrofungi after 3 years of observations (Perini *et al.*, 1999). Intensive exploration in the regional Park of the Madonie recorded more than 600 species in an area of about 400 km^2 (Venturella *et al.*, 2000). A check-list of Italian Basidiomycetes is soon to be published, with other groups of fungi to be added in the near future.

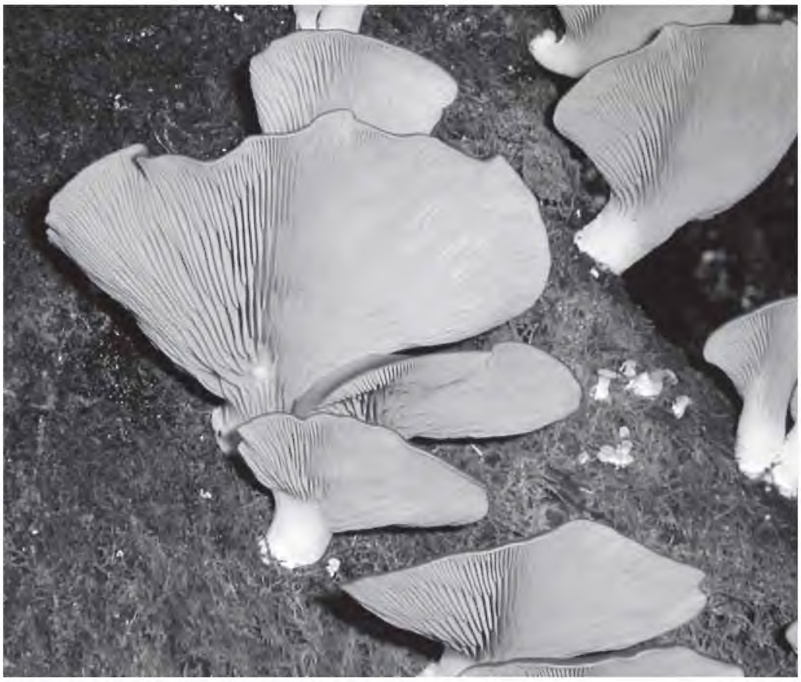
Hericium coralloides, *a rare fungus in Sicily. Photo: Ian Bell (taken in Tasmania)*

Proposals to include fungi from Tuscany and Sicily in regional red-list have been published, with categories in most cases assigned using IUCN criteria. Moreover, some 93 taxa have been identified that could be considered as rare and/or endangered in Italy.

Conservation of fungi in Tuscany

In Tuscany the species proposed for inclusion on red-lists are principally those strictly linked to endangered habitats or at the limit of their area. The well-preserved sandy dune areas of the Natural Reserve of Burano Lake have a very characteristic mycoflora such as *Gyrophragmium dunalii*, *Hydropus mediterraneus* and *Psathyrella ammophila*. A close relation between this last species and the herbaceous plant *Ammophila arenaria* is well-known. The *Ammophiletaea* community, which is the pioneer vegetation on sandy dunes, is considered by the Habitat Directive to be an ecosystem in need of conservation. If the habitat is threatened, so too is the strictly linked mycoflora (Perini & Laganà, 2004). Several other species, such as *Helvella juniperi, Hygrocybe conicoides* and *Tulostoma giovannellae*, growing in sandy coastal dunes, should also be included in a future Red List for Tuscany (Antonini *et al.*, 2002).

Another particular habitat worthy of attention for fungal conservation is peatbogs, which are few and small in Italy compared to those of central-northern Europe. As glacial relicts they have a different conservation requirement due to a sporadic appearance at the limit of their distribution. The very small areas of mountain peatbogs in the Apennine between Tuscany and Emilia-Romagna strongly need conservation. There are a number of interesting species from this habitat which are proposed for the Tuscan Red-List, including *Entoloma poliopus*, *Gymnopilus bellulus*, *Hygrocybe laeta*, *Omphalina oniscus* and *Pholiota myosotis*, all regarded as rare or threatened in central-northern Europe; *Entoloma cuspidiferum* and *Galerina paludosa*, both strictly linked to *Sphagnum* communities; and *Arrhenia lobata* and *Rickenella mellea*, which are



Pleurotus purpureo-olivaceus. *Another species,* Pleurotus nebrodensis, *is a rare and declining fungus in Sicily. Photo: Paul George (taken in Victoria)*

arctic-alpine species and therefore at the limit of their distribution. *Hygrocybe coccineocrenata*, cited as threatened in some European Redlists, is present at all altitudes (Perini *et al*., 2002).

Conservation of fungi in Sicily

In Sicily the main fungal conservation actions relate to a particular taxonomic group: *Pleurotus* growing as saprobes on the root residues of various umbelliferous plants. As with many plants, some fungi are wild relatives of cultivated species, and different strains suitable for cultivation can be obtained from them. There are various wild *Pleurotus* in Sicily, with good organoleptic qualities. The *Pleurotus eryngii* species-complex includes populations of choice edible mushrooms (Zervakis *et al*., 2001). One of these is *Pleurotus nebrodensis*, a rare and declining species from Sicily. It has been known since ancient times, and the present-day natural product is sold in the Madonie territory (northern Sicily) at up to 70 euro/kg. Since it is scarce, the natural product has no real market, but is used by a few restaurants and offered in many traditional recipes.

A project was activated in Sicily in order to safeguard natural populations of *P. nebrodensis* through cultivation. Cultivation is conducted in a tunnel, made of metal arches, covered by a black shade net (Zervakis & Venturella, 2002). Cultivated *Pleurotus* mushrooms retain the same qualities as natural ones. This is not the case with champignons and oyster mushrooms, which when cultivated lose much of the characteristic aroma and flavour of wild varieties. Cultivation provides an additional source of income for indigenous farmers, offers the local populace a product that is cheaper than the natural one and, in parallel, reduces pressures on the natural sites of growth. Recently *P. nebrodensis* was included by the IUCN Species Survival Commission as a Critically Endangered (CR) species in the Top 50 Mediterranean Islands Plant project.

More than 20 rare or infrequent taxa are suitable to be included in a preliminary regional red list for Sicily (Saitta & Venturella, 2005). Examples of species to be included are *Gyromitra esculenta*, *Verpa conica*, *Strobilomyces strobilaceus*, *Phaeolus schweinitzii*, *Hericium coralloides*, *Colus hirundinosus* and *Tulostoma squamosum*.

Conclusion

The European Council for the Conservation of Fungi (ECCF) was established in 1985, and is the conservation body of the newly founded European Mycological Association (EMA). The ECCF has promoted the protection of mushrooms throughout Europe. In recent times the conservation of fungi was included among targets of the European Plant Conservation Strategy, developed by the Planta Europa network and the Council of Europe, and accepted by the Convention on Biological Diveristy (CBD) as part of their Global Strategy.

The inclusion of fungi in the initiatives of the European Plant Conservation Strategy will be a stimulus to mycological activity, particularly in regard to targets 1.2, Red-listing, and 1.4, Identification of Important Plant Areas (IPA) for conservation of fungal biodiversity. Different scientific attempts in identifying hotspots for fungi are underway and efforts should also be made to assure political protection for these areas (Parmasto *et al*., 2004).

References

Alexander, IJ. & Watling, R. (1987). Macrofungi of Sitka spruce in Scotland. *Proceedings of the Royal Society of Edinburgh* 93: 107-115.

Antonini, D., Antonini, M., Laganà, A. & Perini, C. (2002). Macrofungal species proposed for a Tuscan red-list (Italy). Abstracts 7th International Mycological Congress, Oslo.

Courtecuisse, R. (2001). Current trends and perspectives for the global conservation of fungi. In: D. Moore, MM. Nauta, SE. Evans & M. Rotheroe (Eds). *Fungal Conservation. Issues and Solutions*. Cambridge University Press, Pp. 7-18.

Parmasto, E., Perini, C. & Rahko, T. (2004). Attempts to introduce fungi into nature conservation activities. 4th European Conference on the Conservation of Wild Plants. Valencia (Spain).

Perini, C., Bonini, I., Romagnoli, P., Antonini, D., & Antonini, M. (2002). Macrofungi and bryophytes of montane mires (Tuscany, Italy): organisms worthy of conservation. *Feddes Repertorium* 113:152-160.

Perini, C. & Laganà, A. (2004). Conservation and value of fungal diversity in the Mediterranean area: an overview of Tuscan experience. *Mycologia Balcanica* 1: 25-29.

Perini, C., Narducci, R., Barluzzi, C., Laganà, A. & Salerni E. (1999). I funghi in Toscana. Allegato 1. Elenco delle specie censite in Toscana. In: Tofacchi L. & Mannini M. (Eds). *I funghi in Toscana. Mappatura e censimento dei macromiceti epigei.* Bandecchi & Vivaldi, Pontedera, pp. 73-98.

Saitta, A. & Venturella, G. (2005). Materiali per una Lista Rossa dei macomiceti della Sicilia. *Inform. Bot. Ital.* 37 (I, Parte B): 868-869.

Senn-Irlet, B. (1998). Regional patterns of fungi in Switzerland, consequences for the conservation policy. In C. Perini (Ed.). Conservation of fungi in Europe, Proceedings of the 4th meeting of the European Council for the Conservation of Fungi, Vipiteno (Sterzing), Italy. pp. 118-125. Università Siena.

Venturella, G., Perini, C., Barluzzi, C., Pacioni, G., Bernicchia, A., Padovan, F., Quadraccia, L. & Onofri, S. (1997). Towards a Red Data List of fungi in Italy. *Bocconea* 5: 867-872.

Venturella, G., Saitta, A. & La Rocca, S. (2000). A check-list of the mycological flora of Madonie Park (North Sicily). Mycotaxon.

Zervakis, G., Venturella, G. & Papadopoulou, K. (2001). Genetic polymorphism and taxonomic infrastructure of the *Pleurotus eryngii* species-complex as determined by RAPD analysis, isozyme profiles and ecomorphological characters. *Microbiology* 147: 3183-3194.

Zervakis, G. & Venturella, G., (2002). Mushroom breeding and cultivation enhances *ex situ* conservation of Mediterranean *Pleurotus* taxa. In: JMM. Engels et al. (Eds). *Managing Plant Genetic Diversity.* CABI Publishing.

Long-term prospects for conservation of *Cladia ferdinandii* (Lacy Coral Lichen) in the Aldinga Scrub Conservation Park, South Australia

John A. Elix

Department of Chemistry, Faculty of Science, Australian National University, Canberra, A.C.T. 0200. Email: John.Elix@anu.edu.au

Background

The Aldinga Scrub Conservation Park was gazetted in November 1985 to include a small (265 hectare) coastal area of relatively undisturbed native vegetation 46 km south of Adelaide between the townships of Aldinga Beach and Sellicks Beach. It is the last remnant of significant coastal Adelaide Plains mallee over easily disturbed sandy soil.

Cladia ferdinandii (Lacy Coral Lichen) is a relatively rare endemic Australian lichen which is known from scattered sites in south-western Western Australia and several isolated locations in southern South Australia (Filson 1992). The largest colonies of this species in South Australia occur in the Aldinga Scrub Conservation Park where it grows on well-drained sandy soils. Its growth and development are critically dependent upon access to moisture. *Cladia ferdinandii* is a vulnerable species because of its restricted distribution and morphology. When dry it is extremely fragile and readily crushed by trampling or eroded by wind-borne sand. Hence it requires protection by macro-vegetation, typically by associated shrubs and mallee trees.

Current and future status of *Cladia ferdinandii* in the Park

The three major colonies of *Cladia ferdinandii* present in the park (as of April 2005) appear in good health. These colonies have been protected by park authorities by the fencing of relevant areas and by the construction of elevated board-walks over the extensive colonies on the soil along the walking track. However, the long-term ecological viability of the park and its colonies of *Cladia ferdinandii* are severely threatened by two major housing developments. The "Sunday" and "Gemtree" housing developments will place 1222 housing allotments and about 16 km of roads on a 120 hectare site directly abutting the northern border of the park. Construction of the larger of these two proposed developments has already begun. As these new housing developments will significantly affect the overall hydrology and drainage system currently feeding water into the park, they will certainly be detrimental to *C. ferdinandii* and other moisture-dependent species. The reduction of soil moisture coupled with increased litter and disturbance could well lead to the demise of this species within the park.

Cladia ferdinandii*, a rare lichen in South Australia, threatened by housing developments adjacent to Aldinga Scrub Conservation Park. Photo: Heino Lepp*

Reference

Filson, RB (1992). Cladiaceae, *Flora of Australia* 54: 101-106.

Progress and problems in the conservation of Tasmanian lichens

Gintaras Kantvilas

Tasmanian Herbarium, Private Bag 4, Hobart, Tasmania 7001, Australia. Email: Gintaras.Kantvilas@tmag.tas.gov.au

Introduction

Knowledge of Australian lichens has increased dramatically in the last two decades. There have now been four volumes published in the *Flora of Australia* series, there is a current checklist (McCarthy 2003), and papers dealing with the systematics of particular groups, floristics of local areas and the description of new species or new records appear on a regular basis in Australian and international journals. At the State level, information is more patchy and the uneven spread of the limited lichenological expertise in Australia becomes more obvious. Thus the lichen flora of parts of the south-eastern mainland and Tasmania are relatively well documented, with the knowledge supported by extensive, well-curated herbarium collections. However, in other areas, the investigation of lichens tends to be based mainly on occasional forays, and the holdings of the state herbaria in no way reflect the true diversity of species.

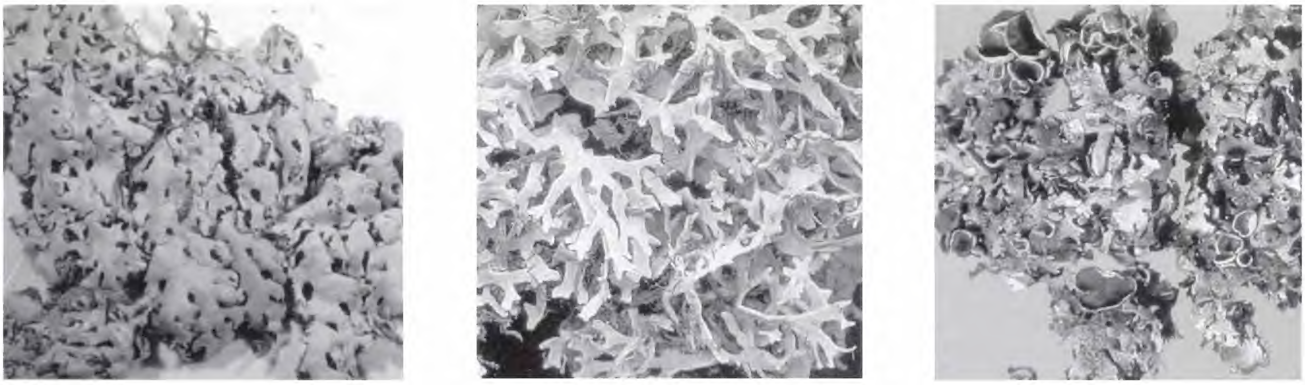
With this level of background knowledge, one might expect that the conservation of lichens would be proceeding apace, but this is not necessarily so. This paper outlines the situation for Tasmania, where, for about 25 years, the author has been involved in lichen collection, survey, systematics and ecological research.

Strategies for lichen conservation

Strategies for the conservation of non-vascular plants in Tasmania were discussed by Brown *et al.* (1994) and Kantvilas (2000). These authors advocated a multi-faceted strategy, including a single-species approach, off-reserve management by prescription, and environmental domain analyses to select reserves that capture all non-vascular plant habitats. Since that time, however, the single-species approach has been applied most widely. Today, the conservation of plants and animals in Tasmania is governed by the *Tasmanian Threatened Species Protection Act 1995*. The *Act* allows for taxa to be listed or delisted through a system of public nominations that are vetted by an independent Scientific Advisory Committee (SAC). The SAC evaluates nominations against strict guidelines and, after a period of public comment, makes a recommendation to the Minister to accept or reject each nomination.

By July 2005, 28 species of lichens had been listed on the Schedules of the *Act*, with a further four species nominated and currently under consideration by the SAC (Table 1).

The criteria for listing are based in part on IUCN criteria, but recognise Tasmanian legislative responsibilities, local knowledge of geography and biology, and expert assessment of threatening processes. For non-vascular plants, the criteria also recognise that information on population size and numbers may be limited and impossible to quantify. Instead, the evaluation of nominations of such taxa takes into account expert knowledge of known distributions, inferred habitat, and assessment of likely threats. Nomination and listing is a complex process, not least because the available knowledge to prepare and vet the nominations is so limited. It may be difficult enough to obtain independent corroboration of data on some relatively distinctive, well-known vascular plant; for small, inconspicuous organisms in specialised groups such as lichens, it may be virtually impossible.



(left to right) Hypotrachyna immaculata *a rare lichen from eucalypt forest*; Xanthoparmelia amphixantha *an endangered lichen from grassland;* Xanthoparmelia mannumensis *a vulnerable lichen from eucalypt forest. Reproduced with permission from Kantvilas et al. (2002)*

Problems

Attempts to incorporate lichens into any conservation strategy face several hurdles, especially because non-vascular plants in general have barely penetrated the psyche of resource managers, conservation biologists, ecologists, planners and other stakeholders. Unfortunately, the word 'plant' is still largely synonymous with 'vascular plant' and estimates of floristic biodiversity rarely take into account that non-vascular plants are likely to be by far the greatest contributors; in cool temperate rainforest, for example, by more than a factor of ten (Kantvilas 1990, Jarman & Kantvilas 1995).

Remarks that lichen conservation biologists need to address include the following:

Lichens are so small and inconspicuous that they are likely to be everywhere if only we looked.

Like any other organism, some lichen species may be ubiquitous, such as the common *Cladia aggregata*, or they may occur in very unusual, highly specialised niches, such as *Roccellinastrum flavescens,* which occurs on the living leaves of Tasmanian endemic alpine conifers. Lichens may be small, but they form clear, definable associations limited by habitat (Kantvilas 1988). Lowland native grasslands in Tasmania provide an excellent example of a fragmented and threatened vegetation formation that supports not only endangered vascular plants but also endangered lichens (Kantvilas & Jarman 2000).

The concept of 'inconspicuous' is also highly subjective. Recording the distribution of some species in Tasmania, for example *Usnea angulata*, has been conducted from the window of a slow-moving car, whereas searching for others involves crawling on all fours with a hand lens.

When working in a familiar environment, an experienced specialist can expect to recognise most species, including crustose lichens, with only a hand lens or the naked eye. Similarly, not all habitats are identical or have the same likelihood of supporting particular species. Interesting rock outcrops or individual trees are all eye-catching to the experienced specialist.

Many lichen species are the same and their taxonomic differentiation is a nonsense.

In the Australian environment, the richest genus by far is *Xanthoparmelia*, and it can certainly be difficult to convince a non-botanist or, indeed, a non-lichenologist that all those greeny coloured lichens are different. The differences between many lichen taxa may be subtle but are often indicative of major genetic differences, and differences in distribution pattern, ecological requirements and other details (e.g. see Kantvilas *et al.* 2002). Lichen taxonomy simply requires somewhat *different* observation skills.

Lichens are small and therefore unimportant in the scheme of things.

It can be a challenge to explain to a land manager why one particular tree can be special because it supports a rare lichen, or that in one corner of a paddock there is an important population of tiny, unusual lichen soil crusts. However, there is much evidence in the literature about the holistic nature of plant communities, of how all the components contribute to community health and to water relations and are intricate components of the web of life.

(top to bottom) Hypotrachyna laevigata *a vulnerable lichen from rainforest;* Cetraria islandica *subsp.* antarctica a *rare lichen from montane vegetation*. Reproduced with permission from Kantvilas et al. (2002)

With more than 40% of Tasmania in a formal reserve, surely all lichens are already protected.

The extensive reservation system in Tasmania means that, by default, many lichens are well represented in secure reserves. However, the criteria by which the reserves are determined, such as wilderness, aesthetic and biological values, are not necessarily good surrogates for lichens. A recent analysis of 48 rare Tasmanian lichens (including the 28 species already listed under the Act) found that almost two-thirds did not occur within any reserve, either by chance because of their intrinsic rarity, or because their habitat fell outside the reserve system (Kantvilas, in press). The belief that all the components of biodiversity, even those that have yet to be documented, will be captured in the reserve system is unsupported by the data.

The Future

The single-species approach to lichen conservation is likely to continue, gradually augmenting the number of formally listed species, even though the effort of compiling primary data and preparing formal nominations arises from the same, limited source. However, these species serve as 'habitat flagships'. For example, the listing of three lowland grassland lichens has meant that less well-known associated species, which themselves will ultimately qualify for listing, are protected to some degree.

Lichens have also been incorporated into some broader focus management projects. For example, Forestry Tasmania's investigation of alternative silvicultural techniques in Tasmania's wet eucalypt forests also involves a study of the responses of bryophytes and lichens (Jarman & Kantvilas 2001a, b).

Nevertheless, a much greater level of education of stakeholders is required before lichens, their diversity and their significance in the landscape are fully appreciated. Likewise, a significantly increased level of resourcing of primary data collection (on taxonomy, floristics, distribution and ecology) is required. Conservation of lichens can only be based on sound knowledge, and no cheap short-cut, aimed at circumventing the lack of basic data, is likely to be effective. There has been much progress towards lichen conservation in Tasmania in recent years. The extent to which the momentum can be maintained, and that real, on-ground outcomes can be realised is rather less certain.

References

Brown, MJ., Kantvilas, G. & Jarman, SJ. (1994). Conservation and reservation of non-vascular plants in Tasmania, with special reference to lichens. *Biodiversity and Conservation* 3: 263-278.

Jarman, SJ. & Kantvilas, G. (1995). A floristic study of rainforest bryophytes and lichens in Tasmania's myrtle-beech alliance. Tasmanian NRCP Report 14. Forestry Tasmania and Department of the Environment, Sport and Territories: Canberra.

Jarman, SJ. & Kantvilas, G. (2001a). Bryophytes and lichens in the Warra LTER Site. I. An inventory of species in *Eucalyptus obliqua* wet sclerophyll forest. *Tasforests* 13: 193-216.

Jarman, SJ. & Kantvilas, G. (2001b). Bryophytes and lichens in the Warra LTER Site. II. Understorey habitats in *Eucalyptus obliqua* wet sclerophyll forest. *Tasforests* 13: 217-243.

Kantvilas, G. (1988). Tasmanian rainforest lichen communities: a preliminary classification. *Phytocoenologia* 25: 355-390.

Kantvilas, G. (1990). Succession in rainforest lichens. *Tasforests* 2: 167-171.

Kantvilas, G. (2000). Conservation of Tasmanian lichens. *Forest Snow and Landscape Research* 75: 357-367.

Kantvilas, G. (in press). Tasmania's threatened lichens: species and habitats. Proceedings of the Seventh Symposium on Collection Building and Natural History Studies in Asia and the Pacific Rim. National Science Museum Monographs: Tokyo.

Kantvilas, G. & Jarman, SJ. (2000). *Xanthoparmelia willisii*- a rare Tasmanian lichen. *Forest Snow and Landscape Research* 75: 401-405.

Kantvilas, G., Elix, JA. & Jarman, SJ. (2002). *Tasmanian Lichens. Identification, Distribution and Conservation Status. I. Parmeliaceae.* Flora of Australia Supplementary Series 15. Australian Biological Resources Study: Canberra.

McCarthy, PM. (2003). *Catalogue of Australian Lichens.* Flora of Australia Supplementary Series 19. Australian Biological Resources Study: Canberra.

Table 1. *Lichens listed or nominated for listing under the* Tasmanian Threatened Species Protection Act 1995 *(in July 2005), showing status and the main vegetation where they occur.*

Bundophoron notatum	endangered	rainforest
Bunodophoron tibellii	nominated	rainforest
Calycidium cuneatum	rare	montane vegetation
Calycidium polycarpum	rare	rainforest
Cetraria islandica subsp. *antarctica*	rare	montane vegetation
Coccocarpia erythroxyli	nominated	*Notelaea* forest
Coccocarpia pellita	nominated	dry eucalypt forest
Erioderma sorediatum	endangered	rainforest
Hypotrachyna immaculata	rare	dry eucalypt forest
Hypotrachyna laevigata	vulnerable	rainforest
Melanelia piliferella	vulnerable	dry eucalypt forest
Menegazzia minuta	endangered	rainforest
Neofuscelia graniticola	rare	dry eucalypt forest
Neofuscelia subloxodella	endangered	dry eucalypt forest
Parmelina pallida	rare	dry eucalypt forest
Parmelina whinrayi	rare	coastal vegetation
Parmeliopsis ambigua	rare	montane vegetation
Parmeliopsis hyperopta	rare	montane vegetation
Parmotrema crinitum	rare	*Melaleuca ericifolia* swamp
Punctelia subflava	extinct	*Melaleuca ericifolia* swamp (?)
Roccellinastrum neglectum	endangered	rainforest
Teloschistes flavicans	rare	coastal vegetation
Xanthoparmelia amphixantha	endangered	lowland grassland
Xanthoparmelia canobolasensis	nominated	dry eucalypt forest
Xanthoparmelia jarmaniae	vulnerable	dry eucalypt forest
Xanthoparmelia mannumensis	vulnerable	dry eucalypt forest
Xanthoparmelia microphyllizans	rare	coastal vegetation
Xanthoparmelia molliuscula	endangered	lowland grassland
Xanthoparmelia oleosa	rare	dry eucalypt forest
Xanthoparmelia vicaria	rare	dry eucalypt forest
Xanthoparmelia vicariella	rare	dry eucalypt forest
Xanthoparmelia willisii	endangered	lowland grassland

Variation in Cool Temperate Rainforest lichens of Victoria: implications for conservation

Sharon F. Morley[1] *and Maria Gibson*[2]

[1]*Department of Primary Industries, Knoxfield, Private Bag 15, Ferntree Gully Delivery Centre, Victoria, 3156.*
[2]*Plant Ecology Research Unit, School of Biological and Chemical Sciences, Deakin University, Burwood, Victoria, 3125*
Email: maryg@deakin.edu.au

Effective conservation of rainforest lichens depends on an understanding of how lichen species are distributed in relation to different patches of rainforest. We have investigated lichen species richness in Cool Temperate Rainforests in Victoria in the Otways, Yarra Ranges, Baw Baw and Errinundra National Parks, using replicated quadrat-based sampling (Ford 2001; Morley & Gibson 2004). For each tree species present, five representative trees from each of four pre-defined size classes were sampled for their lichen flora up to a height of 2 m, this being the practical limits of accessibility. Canopy species were collected from recently fallen twigs.

In all, more than 900 trees representing 15 different vascular species were sampled. A total of 165 lichen species were recorded. Of these, 84 were macrolichens and 81 were microlichens, 108 occurred in the canopy and 114 on the lower trunks, with 55 species common to both habitats. Non-metric multidimensional scaling on the percentage cover of lower trunk lichen communities showed quadrats from the Otways and Errinundra to be quite distinct from each other and from the Baw Baw and Yarra Ranges quadrats which grouped together. This mirrored the results for the vascular plants showing that distribution of lichen species was dependent on distribution of host species. Further, within the forests of each region, species richness was quite variable (Fig. 1).

Variation of lichens with size and comparative age of rainforest pocket also was examined. Small, regenerating rainforest pockets were floristically depauperate, generally dominated by ubiquitous, widespread species and contained few rare species. Conversely, large, mature stands contained a much more diverse lichen flora with high proportions of both common and rare species. Some small rainforest pockets containing large and extra large *Nothofagus cunninghamii* trees hosted a lichen flora similar to large, mature stands, suggesting that even small stands may act as refuges for lichens, as long as suitable microhabitats exist. Furthermore, this implied that the successional stage of the rainforest stand was more critical than pocket size in the establishment or subsistence of rainforest lichen communities.

Our findings have important implications for conservation of rainforest lichens which can be expanded to lichens of other habitats. Firstly, within a broad vegetation group, it is necessary to conserve the different sub-classes; secondly, it is necessary to conserve several examples of each sub-class to ensure maximum biodiversity and, thirdly, older successional stages should be protected at all costs regardless of size, as these contain the highest biodiversity and include the greatest number of rare species.

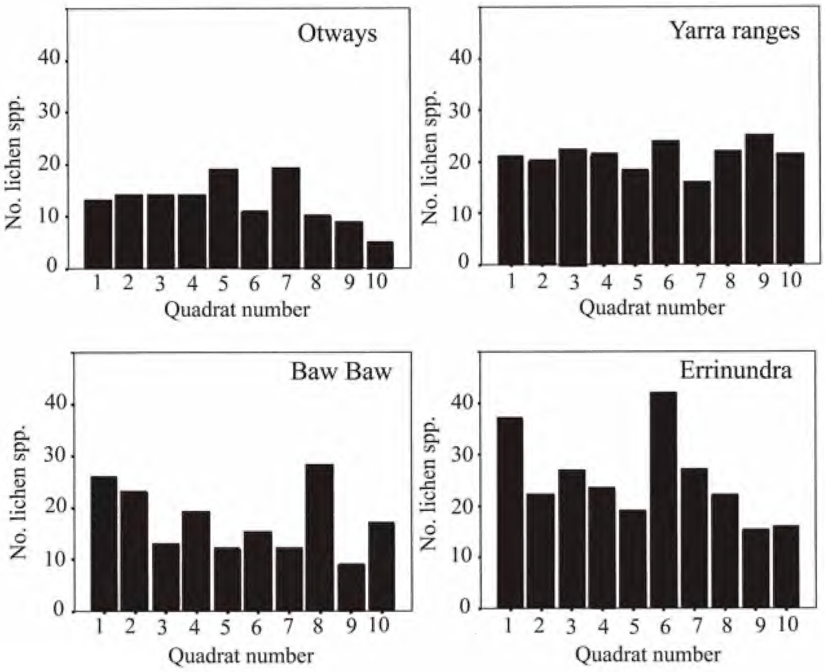


Figure 1. Lichen species richness in different quadrats in Rainforest in four different areas in Victoria

References

Ford, SF. (2001). The lichens of Cool Temperate Rainforests in Victoria. PhD. thesis. Deakin University.

Morley, SF. & Gibson, M. (2004). Cool Temperate Rainforest lichens of Victoria, Australia: floristics and distribution. *The Bryologist* 107: 62-74.

Rare and endangered liverworts: A new area of conservation in New Zealand

M.J. von Konrat[1], D.S. Glenny[2], P.J. de Lange[3], J.J. Engel[1], J.E. Braggins[4] & M.A.M. Renner[5]

[1]*Department of Botany, The Field Museum, Chicago, U.S.A. Email: mvonkonrat@fieldmuseum.org.*
[2]*Landcare Research, Lincoln, New Zealand.* [3]*Terrestrial Conservation Unit, Department of Conservation, Auckland, New Zealand.*
[4]*John Braggins Consultants Limited, Auckland, New Zealand.*
[5]*Institute of Wildlife Research, School of Biological Sciences, University of Sydney, NSW.*

In contrast to the wealth of information available on the vertebrate animal and seed plant groups of New Zealand, the taxonomic diversity, distribution, ecology and reproductive biology of New Zealand liverworts is largely unknown. This is alarming considering the liverwort flora of New Zealand is of worldwide significance and the fact that liverworts form both a conspicuous and important component of many New Zealand ecosystems.

Ecological and biological significance of liverworts

The ecological roles of liverworts in temperate and tropical ecosystems include contributing to nutrient cycles (Coxson, 1992) and canopy humus (Ingram & Nadkarni, 1993), forming microhabitats for insects and microorganisms, and ameliorating the effect of heavy rains (Pócs 1980). The chemical compounds of some liverworts are also particularly noteworthy because they have important biological properties such as activity against certain cancer cell lines, anti-bacterial, anti-microbial, and anti-fungal activities (Asakawa 1995; Asakawa *et al*. 2003).

Global significance of the New Zealand liverwort flora

New Zealand has about 5-10% of the world's liverwort flora including about 300 endemic taxa (Table 1). Of worldwide significance is that greater than 60% of the liverwort families and over 40% of the genera are represented in New Zealand. Furthermore, of the 18 genera endemic to New Zealand, 16 genera are monotypic (a genus with only one species), e.g., *Jubulopsis* and *Xenothallus*.

Table 1. Biodiversity statistics for liverwort families, genera, and species (Number of endemic taxa in brackets).

Region	No. of Families	No. of Genera	Lower Ranks
Worldwide	74	377	6000-8000
New Zealand	49 (2)	155 (18)	642 (304)

The taxonomic and evolutionary significance of the New Zealand liverwort flora also is exemplified by the presence of a high number of taxonomically isolated species-poor families that have disjunct distributions. Examples of taxa occurring in New Zealand and Australia are *Neogrollea* (Fig. 1,2) (Neogrolleaceae) and *Trichotemnoma* (Trichotemnomataceae), both of which are in monotypic families, and the monotypic genus *Chaetophyllopsis*.

Assigning categories of threat

de Lange and Norton (1998) proposed a New Zealand-based risk classification system for uncommon taxa to overcome several shortcomings presented in other systems, e.g., the IUCN threat categories, particularly with regard to insular and narrow-range endemics. Their classification system has been further developed to produce the New Zealand Threat Classification System (Molloy *et al*. 2002), which is used by the New Zealand Department of Conservation.

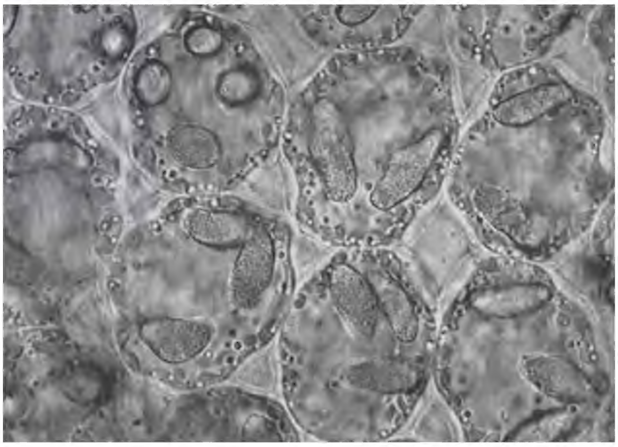


Figure 1. Cellular oil-bodies of Neogrollea notabilis.

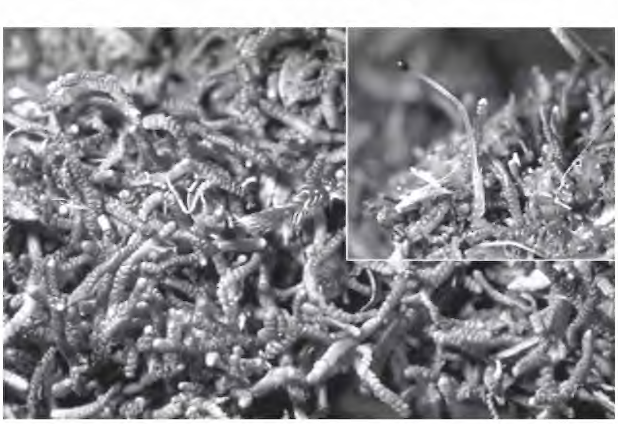


Figure 2. Habit of Neogrollea notabilis *with sporophyte as inset, ranked "Nationally Endangered" in New Zealand, but also known from Tasmania, Australia.*

Difficulties applying threat classification systems to bryophytes

Data is seldom available to bryologists that makes it possible to conduct population viability analyses, calculate generation time, or estimate the number of mature individuals or total population sizes. Evaluation of species against threat categories is mostly based on numbers of collections and inference from available data. Furthermore, some of the criteria are either not applicable, inappropriate, or present special challenges when dealing with bryophytes. For example, it is difficult to apply the term 'individual' as defined by Molloy *et al.* (2002): 'the number of mature individuals is defined as the number of known, estimated or inferred to be capable of reproduction'. In setting forth guidelines for the application of the revised IUCN threat categories specifically to bryophytes, Hallingbäck *et al.* (1998) noted that it is impossible, without genetic studies of each unit, to determine what constitutes an individual bryophyte. We promote a pragmatic definition of an individual and regard a single discrete 'patch' or 'tuft' as an individual.

Current and perceived threats

Threats to the New Zealand biota are generally well known and include habitat loss, deterioration, fragmentation and invasive plant and animal species. From the bryophyte perspective, the exotic clubmoss *Selaginella kraussiana* is a serious threat to many New Zealand liverworts because of similarity in habitat preference. Moreover, the impact of other pressures on liverworts and bryophyte assemblages, such as micro-habitat loss and habitat fragmentation, has not been previously investigated within a New Zealand context (Braggins *et al.* 2001). Studies elsewhere have concluded that the size and shape of fragments had a significant effect on habitat heterogeneity, and bryophyte and lichen diversity (Gignac & Dale 2005). This is relevant to New Zealand where there are large tracts of forests as well as many fragmented systems. Interestingly, Gignac (2001) concluded that because of the close association of bryophytes with climatically sensitive habitats and ecosystems, bryophytes might serve as potential indicators of large-scale changes before the habitat or ecosystem itself is affected.

Taxonomic knowledge of New Zealand liverworts

Although there have been a considerable number of recent taxonomic publications on the New Zealand liverwort flora, many taxonomic problems still need serious study, and data relevant to distribution ranges and ecology are still incomplete. Hence few regions can be considered extensively inventoried for liverworts. Attesting to this are: recent new records of two genera new to New Zealand, *Brevianthus* (Glenny 1999) and *Mnioloma* (Renner 2003); scores of new species in genera such as *Lepidozia* (Engel & Schuster 2001; Engel 2004); as well as regular new species record with an average of five species per year added to the New Zealand liverwort flora.

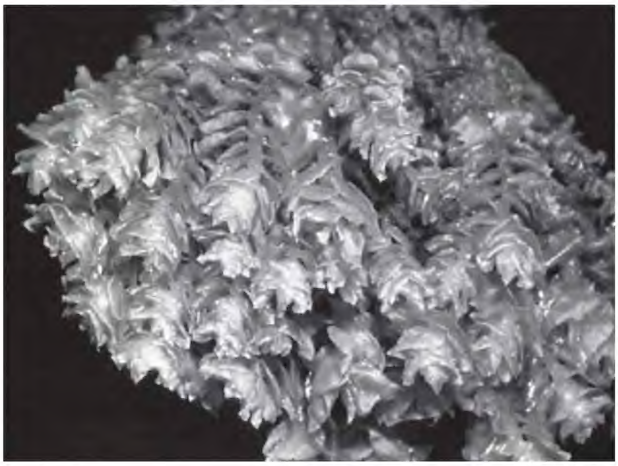


Figure 3. Habit of Schistochila nitidissima*, known only from scant collections from North Island, New Zealand, and considered under threat from the invasive weed* Selaginella kraussiana*.*

In order to help fill gaps in knowledge of New Zealand liverwort biodiversity, a collaborative project between the Field Museum, Chicago and Landcare Research, New Zealand is underway to produce a three-volume Liverwort Flora of New Zealand. The project is the first to be attempted since Hooker's 1855 *Flora of New Zealand*.

Conservation Status of New Zealand Liverworts

An update to the previous threatened bryophyte list (Hitchmough, 2002) is to be published in a forthcoming issue of *Australasian Bryological Newsletter*. In developing the list, the threat classification system outlined by Molloy *et al.* (2002) was applied. The precautionary principle to species conservation advocated by Molloy *et al.* (2002) and the IUCN was also adopted. This emphasizes the importance of attempting to allocate threat status to even poorly known species by estimating and extrapolating the current or potential threats into the future. This has resulted in many undescribed liverworts on the threatened list, particularly in the Data Deficient category, and suggests that much taxonomic work remains to be done. The list thus also indicates priorities for taxonomic research.

The revised list comprises 172 taxa, representing an increase of 82 taxa on the previous listing of Hitchmough (2002). The increase is due in part to the inclusion of some 32 undescribed taxa, ranging from those awaiting publication through to entities whose distinctness has yet to be ascertained. The increase also reflects the renewed efforts to ascertain the New Zealand liverwort flora and, as a consequence, better networking within the bryological community.

Table 2. Number of taxa of New Zealand liverworts assigned to a category of threat. (Categories as defined by Molloy et al.*, 2001).*

Taxon Status	Nationally Endangered	Nationally Vulnerable	Nationally Critical	Sparse	Restricted Range	Data Deficient
Described	10	1	57	23	22	26
Undescribed	2	—	3	2	8	17

Sixty-eight described taxa are collectively rated as "Acutely Threatened" (comprising the categories "Nationally Endangered", "Nationally Vulnerable", and "Nationally Critical") and 26 described taxa and 17 undescribed entities are assigned to the Data Deficient category (Table 2). There are also species on the list that are apparently uncommon in New Zealand but common outside of New Zealand, e.g., *Dumortiera hirsuta*, and these have been qualified with "Secure Overseas."

Conclusions and priority areas for investigation

A benefit of listing has been that this has stimulated fieldworkers to search for threatened liverworts, and a considerable effort has gone into searching for many species in the last decade. Although this has helped the current listing, it is clear that future priorities now include: 1) identify distributions more completely as well as accumulate ecological data; 2) identify and research further both present and potential threats to liverworts, such as forest fragmentation; 3) taxonomic revision of critical taxa; 4) accumulate data on reproductive biology; and 5) assess poorly investigated habitats and ecological regions, including the many offshore islands that have not been well inventoried. These avenues of research and investigation will lead to new insights in the study of New Zealand liverwort diversity, geography and conservation. As stressed in the preamble to the IUCN threat categories (2001), Red List threat categories alone are not sufficient to determine priorities for conservation. A system of assessing priorities for action should also include other factors, such as international responsibilities, taxonomic uniqueness, logistics, chances of success and costs (Hallingbäck *et al.* 1998).

References

Asakawa Y. (1995). Chemical constituents of the bryophytes. In: Herz W., Kirby GW., Moore RE., Steglich W. & Tamm C. (Eds). *Progress in the chemistry of organic natural products.* Vol. 65. Wien: Springer.

Asakawa, Y., Toyota, M., von Konrat, M. & Braggins, JE. (2003). Volatile components of selected species of the liverwort genera *Frullania* and *Schusterella* (Frullaniaceae) from New Zealand, Australia, and South America: A Chemosystematic approach. *Phytochemistry* 62: 439-452.

Braggins, JE., Engel, JJ., von Konrat, MJ. & de Lange, PJ. (2001). An investigation of rare and threatened liverworts: An overlooked area of conservation in the New Zealand botanical region. Botanical Society of America (Abstracts) [http://www.botany2001.org/].

Coxson, D. (1992). Nutrient release from epiphytic bryophytes in tropical montane rain forest. *Canadian Journal of Botany* 69. 2122-2129.

de Lange, PJ. & Norton, DA. (1998) Revisiting rarity: a botanical perspective on the meanings of rarity and the classification of New Zealand's uncommon plants. In: R. Lynch (Ed.). *Ecosystems, entomology and plants.* The Royal Society of New Zealand Miscellaneous Series 48: 145–160.

Engel, JJ. (2004). Austral Hepaticae 36. A new species of *Lepidozia* from New Zealand, together with an assessment of Subg. *Austrolepidozia* (Schust.) Schust. *Journal of the Hattori Botanical Laboratory* 96: 273-279.

Engel, JJ. & Schuster RM. (2001). Austral Hepaticae 32. Revision of the genus *Lepidozia* (Hepaticae) for New Zealand. *Fieldiana, Botany* 42: 1-107.

Gignac, LD. (2001). Bryophytes as indicators of climate change. *The Bryologist* 104: 410 –420.

Gignac, LD. & Dale, MRT. (2005). Effects of fragment size and habitat heterogeneity on cryptogam diversity in the low-boreal forest of western Canada. *The Bryologist* 108: 50-66.

Glenny, D. (1999). *Brevianthus flavus* new to New Zealand. *Australasian Bryological Newsletter* 42: 3.

Hallingbäck, T., Hodgetts, N, Raeymaekers, G., Schumacker, R., Sérgio, C., Söderström, L., Stewart, N. & Vána, J. (1998). Guidelines for application of the revised IUCN threat categories to bryophytes. *Lindbergia* 23: 6-12.

Hitchmough, RA. (2002). (ed.) New Zealand threat classification system lists. Biodiversity Recovery Unit, Department of Conservation, Wellington.

IUCN (2001). *IUCN Red List Categories and Criteria : Version 3.1.* IUCN Species Survival Commission. IUCN, Gland, Switzerland and Cambridge, UK.

Ingram, S. & Nadkarni., N. (1993). Composition and distribution of epiphytic organic matter in Neotropical cloud forest, Costa Rica. *Biotropica* 25: 370-383.

Molloy, J., Bell, B., Clout, M., de Lange, P., Gibbs, G., Given, D., Norton, D., Smith, N. & Stephens, T. (2002). Classifying species according to threat of extinction. Biodiversity Recovery Unit, Department of Conservation, Wellington.

Pócs, T. (1980). The epiphytic biomass and its effect on the water balance of two rain forest types in the Uluguru Mountains (Tanzania, East Africa). *Acta Bot. Acad. Scient. Hung.* 26:143-167.

Renner, MAM. (2003). *Mnioloma fuscum* (Marchantiopsida: Calypogeiaceae), an unexpected addition to the indigenous flora of New Zealand. *Journal of Bryology* 25: 287–291.

Scott, GAM., Entwisle, TJ., May, TW. & Stevens, GN. (Eds) (1997). *A conservation overview of Australian non-marine lichens, bryophytes, algae and fungi.* Environment Australia, Canberra.

Bryophyte reproductive ecology and conservation

Maria Gibson

Plant Ecology Research Unit, School of Biological and Chemical Sciences, Deakin University, Burwood, Victoria, 3125;
Email: maryg@deakin.edu.au

Studies of bryophyte reproduction are essential for their long-term conservation. Such studies provide information on population establishment, maintenance and factors that influence species survival and their ability to adapt to changes (Longton 1994). The reproductive biology/ecology of bryophytes has received little attention in the Southern Hemisphere. In Australia, the reproductive biology of four *Dicranoloma* species (Milne 2001), *Wijkia extenuata* (Sinclair & Gibson 2000) and *Atrichum androgynum* (Biggs & Gibson 2003) is known. The comparative sexuality and phenology of stream-rock and stream-side bryophytes at Cement Creek have been studied (Carrigan & Gibson 2003). For the Australian wet tropics, Beckmann (1993) and Ramsay (1987) investigated the reproductive biology of marsupial liverworts and mosses, respectively.

Reproductive ecology

Studies on reproductive ecology seek reasons connecting patterns of survival, reproduction, fitness and environmental influences (Stark 2002). Reproductive studies can include: allocational biology, spore production and dispersal, life strategy, regeneration, gamete dispersal, sex ratios, tissue viability over time and interplay between asexual and sexual reproduction (Austrheim *et al.* 2005) as well, of course, as population genetics. If such factors are not understood, correct management for sustainable long-term conservation is impossible. Australian studies on the topic are few, however a considerable number of studies have been completed in the Northern Hemisphere. Results from these studies can be used as a guide for development of management protocols in Australia.

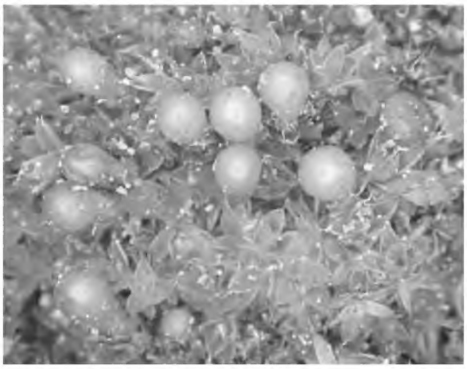
Sexual reproduction

Bryophytes can reproduce sexually and/or asexually. Sexual reproduction involves an alternation of generations. The dominant generation is the gametophyte, which bears the male and female reproductive structures. Multiflagellated sperm are transported, usually via water, to the egg. If no water is present, fertilization does not occur. With increasing fragmentation of natural habitats to smaller and smaller patches, moist habitats become dry and sexual reproduction will diminish, so conservation strategies must take into account patch size of habitat.

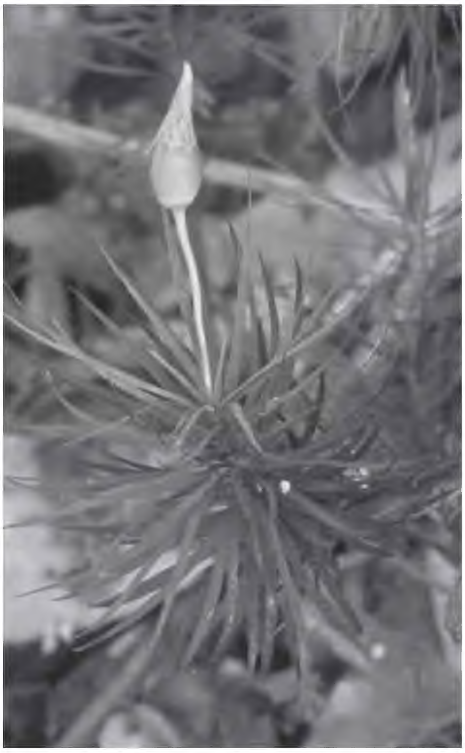
Fertilization of the egg may result in development of the sporophyte, which remains dependant on the gametophyte. The number of spores produced versus the number of gametophytic stems has been used as a measure of reproductive fitness (Miles & Longton 1987) which, in turn, has been used to determine which species or area has priority for conservation. Many species, however, are not known to reproduce sexually at all. Other species may reproduce sexually in one area but not another and within an area, one population may reproduce sexually while another nearby population does not, or reproduction is much reduced (Herrnstadt & Kidron 2005; pers. ob. in Victoria).

Many factors affect whether or not sexual reproduction occurs successfully. For most species investigated (Stark 2002), different reproductive events occur at particular seasons. If factors pertaining to any of the seasons are changed, for example moisture levels or temperature, sexual reproduction may not occur. Indeed, environmental stress is believed to be responsible for decreased sexual reproduction (de Kroon & van Groenendael 1997), including not only the macroclimatic scale that deals with seasons but also the microclimate. The latter was demonstrated in *Bryum dunense*, where, although sexual organs were formed,

Rainforest gully with abundant bryophytes on rocks and tree ferns at Mt Donna Buang, Victoria. Photo: Matt Dell sporophytes were less common in exposed as compared to partially shaded microhabitats (Herrnstadt & Kidron 2005). Thus, it is important to consider the provision of different micro-environments when conserving habitat to cater for different species of bryophyte and their potential requirements for sexual reproduction, e.g. a range of logs at different stages of decay and a variety of potential hosts or shade providers.



The rare moss Pleurophascum occidentale*, showing the globular capsules, which are rarely produced in nature. Photo: Niels Klazenga*



The moss Dawsonia*, showing the sporophyte (upper portion, with capsule seated on seta) arising from gametophyte (leafy lower portion). Photo: Anneke Veenstra-Quah*

Timing of reproductive events

Generally, populations of a species from one region will show the same timing of reproductive events (Stark 2002), but there may be differences across different regions (Austrheim *et al*. 2005). Australia has a wide latitudinal spread, so an understanding of the factors affecting reproduction of a particular species in one area may not translate to another area. Thus, it is important to understand the processes occurring at the local scale to ensure survival of a particular species in that area.

Sex ratios

Male rarity in dioecious species appears to be characteristic of bryophytes, particularly in high-stress habitats (Stark *et al*. 2005). This could mean that there are more females than males or that the males are present but simply not expressing sex. All the reproductive studies conducted on Australian mosses have shown a female bias in their sex ratios, in terms of sex expression. Does this suggest stress? It is likely. Male structures normally require a longer period to mature, and thus higher energy expenditure to express sex (Stark 2002). Indeed, Cronberg *et al.* (2003) found that non expressing individuals were more likely to be genetic males. Nutrients are taken into the hydrated bryophyte directly through the plant body. The uptake of nutrients, therefore, is directly affected by moisture levels in the habitat. Moisture levels also indirectly affect nutrient uptake in that increased levels lead to increased density of a population. This, in turn, leads to longer periods of the population being in the hydrated state, which allows increased levels of nutrient uptake.

Fragmentation of the Australian landscape has led to increased drying. Rapid desiccation and high temperature stress require the synthesis of repair proteins (Oliver & Wood 1997). This could affect nutrient resource allocation patterns away from sex expression (Stark *et al*. 2005) so that there is a female advantage in stressed areas as female sex expression is relatively cheap compared to males. Without correct conservation management, males may become extinct, which would have genetic consequences that could affect the long term conservation of species. Certainly, in some areas, and for some species, males are unknown (Stark *et al.* 2005).

Some recommendations

The recommendations below deal specifically with bryophyte reproduction. The reader is referred to Scott *et al*. (1997), Ryan (2002) and Pharo (2005) for conservation recommendations dealing with bryophytes generally.

For long-term conservation of bryophytes, it is necessary to:

- Increase studies dealing with all facets of reproduction.
- Increase funding for research into reproductive ecology of bryophytes, particularly for honours and post-graduate research.
- Conserve many examples of a habitat type to ensure conditions favorable to both sexes of dioecious bryophytes.
- Develop conservation protocols taking into account reproductive strategies, to ensure long-term conservation of bryophytes.
- Encourage taxonomists and collectors to note the sexual and reproductive status of bryophytes lodged in herbaria.
- Develop a database with the sexual and reproductive status of bryophytes.
- Include bryophytes in the collections of botanic gardens, particularly known endangered bryophytes. These could then be used for transplanting back into the wild should conditions become appropriate.

References

Austrheim, G., Hassel, K. & Mysterud, A. (2005). The role of life history traits for bryophyte community patterns in two contrasting alpine regions. *The Bryologist* 108: 259-271.

Beckmann, KG. (1993). *The biology and taxonomy of some Australian marsupial liverworts.* PhD. thesis. Monash University.

Biggs, L. & Gibson, M. (2003). The sexuality of *Atrichum androgynum* (C. Müll.) Jaeg. (Musci: Polytrichaceae) in Wet Sclerophyll and Cool Temperate Rainforest of Victoria, Australia, *Hikobia* 14: 71-74.

Carrigan, C. & Gibson, M. (2003). Comparative sexuality of conspecific stream-side and stream-rock mosses. *Hikobia* 14: 71-74.

Cronberg, N., Andersson, K., Wyatt, R. & Odrzykoski, IJ. (2003). Clonal distribution, fertility and sex rations of the moss *Plagiomnium affine* (Bland.) T. Kop. in forests of contrasting age. *Journal of Bryology* 25: 155-162.

Herrnstadt, I. & Kidron, GJ. (2005). Reproductive strategies of *Bryum dunense* in three microhabitats in the Negev desert. *The Bryologist* 108: 101-109.

de Kroon, H. & van Groenendael, JM. (1997). *The ecology and evolution of clonal plants*. Backhuys, Leiden.

Longton, RE. (1994). Reproductive biology in bryophytes the challenge and the opportunity. *Journal of the Hattori Botanical Laboratory* 76: 159-172.

Miles, CJ. & Longton, RE. (1987). Life history of the moss, *Atrichum undulatum* (Hedw.) P. Beauv. *Symposia Biologica Hungarica* 35: 193-207.

Milne, J. (2001). Reproductive biology of three Australian species of *Dicranoloma* (Bryopsida, Dicranaceae): Sexual reproduction and phenology. *The Bryologist* 104: 440-452.

Oliver, MJ. & Wood, AJ. (1997). Desiccation tolerance in mosses, pp. 1-26. In T. Koval (Ed.). *Stress-inducible processes in higher eukayotic cells*. Plenum Press, New York.

Pharo, E. (2005). *Threats to cryptogam conservation: an Australian perspective.* VIIIth Australasian Bryophyte Workshop, Paluma.

Ramsay, HP. (1987). Studies on the reproductive biology of some mosses from the Australian wet tropics. *Proceedings of the ecological Society of Australia* 15: 273-279.

Ryan, P. (2002). *Overview of non-vascular plants, lichens, fungi and algae in the Goulburn Broken Catchment: their status, threats and management*. Ecolines Environmental Services, Canberra.

Scott, GAM., Entwisle, TJ., May, TW & Stevens, GN. (1997). *A conservation overview of Australian non-marine lichens, bryophytes, algae and fungi.* Environment Australia, Canberra.

Sinclair, B. & Gibson, M. (2000). Sexuality of *Wijkia extenuata* (Brid.) Crum in wet Victorian forests. *The Victorian Naturalist* 117: 166-171.

Stark, LR. (2002). Phenology and its repercussions on the reproductive ecology of mosses. *The Bryologist* 105: 204-218.

Stark, LR., McLetchie, D. & Mishler, BD. (2005). Sex expression, plant size, and spatial segregation of the sexes across a stress gradient in the desert moss *Syntrichia caninervis*. *The Bryologist* 108: 183-193.

Managing bryophyte diversity on limestone karst systems

Alison Downing & Ron Oldfield

Department of Biological Sciences, Macquarie University, NSW 2109. Email: adowning@rna.bio.mq.edu.au

Bryophytes on limestone karst in south-eastern Australian

Karst is the name given to landscapes created by rock, usually limestone or dolomite, dissolving in water, rather than being eroded by wind and water. Karst typically includes caves, sink holes and underground streams and in south-eastern Australia mostly occurs as small, isolated outcrops.

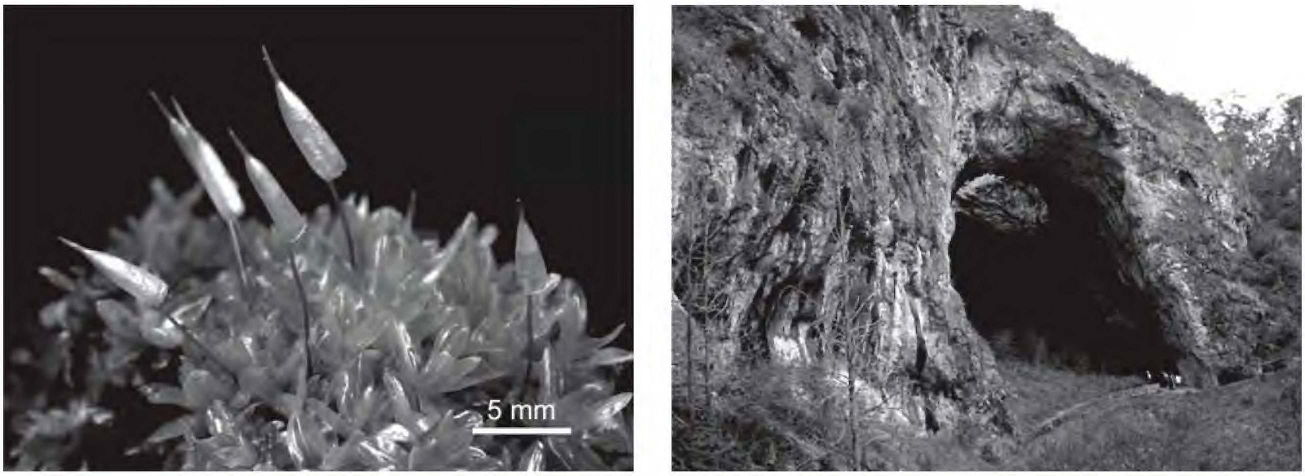
Studies of bryophytes (mosses and liverworts) on limestone karst in south-eastern Australia, including Jenolan, Wombeyan, Bungonia and Wellington Caves, have shown that it is possible to recognise a limestone substrate by the combination of bryophytes that it supports. Bryophytes are far more abundant on limestone than on non-limestone, not only in the amount of cover on the ground and in the number of species present but also in the frequency with which each species occurs. Mosses from the families Pottiaceae and Bryaceae, and thallose liverworts from the order Marchantiales, dominate the bryoflora. Certain key species, including *Didymodon torquatus,* either *Bryum pachytheca* or *Bryum dichotomum, Fissidens megalotis* and *Gigaspermum repens*, are present at each site. Surprisingly few species, such as *Encalypta vulgaris, Pseudoleskeopsis imbricata* and *Orthotrichum cupulatum* var. *cupulatum*, occur exclusively on limestone (Downing, 1992).

A surprising number of species that commonly occur on limestone karst are species more usually associated with arid and semi-arid areas of Australia (Downing & Selkirk, 1993). Also, the presence of sheep and cattle on limestone significantly increases the number of introduced and cosmopolitan species of bryophytes (Downing, 1992).

Mosses at Yarrangobilly Caves

Yarrangobilly Caves, in the Southern Alps of New South Wales, were discovered in 1834, used by graziers from 1861 onwards and developed as a tourist destination from the 1890s. In 1906, W.W. Watts collected mosses in the vicinity of Yarrangobilly Caves and published a species list (Brotherus & Watts, 1912). In 1993 we surveyed the mosses at Yarrangobilly and compared our results with Watts' 1906 collections (Downing *et al.* 1997).

In 1906 the assemblage of mosses recorded by Watts was, to a limited extent, similar to the assemblages that we have recorded in recent times on other limestone outcrops. However, there were differences and key species that typify



(left to right) Encalypta vulgaris *- one of the few mosses occurring exclusively on limestone; The Glory Hole at Yarrangobilly Caves in Kosciuszko National Park. Bryophytes are abundant on moist soil and rock near the cave entrance. Photograph: the authors*

limestones were not present. By 1993 the assemblage at Yarrangobilly had changed significantly and was very similar to those of other south-eastern Australian limestone karst locations and all key species were present.

Differences 1906 - 1993

The disappearance of some species appears to be directly related to changes following European settlement. A swamp where Watts recorded unusual and rare species was redeveloped as a thermal pool. Similarly, construction of roadside drains appears to have led to the disappearance of others. Many creeks are now so overgrown with exotic weeds such as species of *Rosa*, *Rubus* and *Hypericum* that light levels are too low for the survival of aquatic bryophytes.

In 1993, most of the species collected by Watts were still present but an additional 36 taxa were recorded. Many of these were probably introduced as a result of human activities, carried in on wheels of vehicles, on hoofs of animals, on boots and shoes, on building materials and garden plants. They include many introduced and cosmopolitan mosses which are now abundant in the vicinity of buildings, on walls, in picnic areas and along roads and paths.

Epiphytic species now present grow on rough bark of exotic trees and shrubs, and were possibly introduced when exotic plants were first brought to and planted at Yarrangobilly. Some species have become more abundant, in particular along paths or roadsides where silica-based rock has been used over limestone rock. From the 1830s until 1972, sheep and cattle were moved through the Yarrangobilly valley to graze on summer alpine pastures probably resulting in further introductions.

Many of the species now found at Yarrangobilly are arid zone species and may have been transported by dust storms. For colonisation to be successful, three elements are necessary: a suitable substrate, a source of propagules, and a means of transport. Prior to European settlement, there would have been natural ground cover of grasses, herbs and leaf litter. From 1900 until the present, construction of roads, paths, buildings, farms and gardens has provided a constantly changing environment of disturbed soil or rock surfaces suitable for bryophyte colonisation from propagules transported by dust storms from semi-arid and arid areas of western Victoria, New South Wales and South Australia. The rough, fissured bark of exotic trees is also a substrate readily colonised by epiphytic arid zone mosses unlike the shedding bark of eucalypts.

Managing bryophyte diversity

Following the study at Yarrangobilly, it is apparent that most limestone karst systems developed as tourist destinations in south-eastern Australia have similar bryophyte assemblages because all have been developed in a similar fashion. In order to maintain the bryophyte diversity it is essential to minimise disturbance to the natural environment. We present the following suggestions:

1. Construct all buildings outside limestone karst areas.
2. Keep construction of paths and roads to a minimum.
3. Wherever possible build paths using limestone rock. Avoid using rock of other chemistry, particularly siliceous rock. Raised pathways can be an alternative.
4. Exclude sheep and cattle.
5. Retain natural vegetation wherever possible, landscape with local native plant species.
6. Avoid planting exotic trees and shrubs.
7. Implement a bushland regeneration program to remove existing weed species.
8. Protect natural water features, such as streams, pools, swamps, bogs and heath.
9. Revegetate stream banks with native plants to allow light to reach watercourses.

Conclusion

Over the last 100 years, there has been an increase in the number of species of mosses that grow on south-eastern Australian limestones. Most of these introductions can probably be attributed to changing land use following European settlement and the subsequent development of caves as tourist destinations. It is probably too late to implement many of our management suggestions at most of the existing tourist caves, but they may be useful in the development of new tourist areas and in minimisation of further introductions to areas already developed.

References

Brotherus, VF. & Watts, WW. (1912). The mosses of the Yarrangobilly Caves District, N.S.W. *Proceedings of the Linnean Society of New South Wales.* 37: 363-382.

Downing, AJ. (1992). Distribution of bryophytes on limestone in Eastern Australia. *The Bryologist* 95: 5-14.

Downing, AJ. & Selkirk, PM. (1993). Bryophytes on the calcareous soils of Mungo National Park, an arid area of southern central Australia. *Great Basin Naturalist* 53: 13-23.

Downing, AJ. Selkirk, PM. & Oldfield, RJ. (1997). The mosses of the Yarrangobilly Caves District, New South Wales, Australia. A Review of the mosses collected by the Reverend W.W. Watts in 1906. *Journal of the Hattori Botanical Laboratory* 82: 105-121.

Biological soil crusts: nature's environmental watchdogs

David Eldridge

Department of Infrastructure, Planning and Natural Resources, c/- School of Biological, Earth and Environmental Sciences, University of NSW, Sydney, NSW, 2052. Email: d.eldridge@unsw.edu.au

Studies in the response of ecosystems to human-induced change have traditionally tended to focus on the more visible organisms such as mammals, birds, vascular plants and even invertebrates. An often neglected, but functionally important group of organisms is the non-vascular plants, found across all the major biomes, from sub-arctic boulderfields, to tropical rainforests and sandy deserts. In Australia they are found in landscapes ranging from the Hawkesbury sandstone around Sydney, to sand dunes and gibber plains of the Great Victoria Desert. Non-vascular organisms occupy habitats as diverse as tree trunks, coarse woody debris, rock, soil and decomposing organic material.

The soil inhabiting (terricolous) non-vascular group of organisms (they are not really true 'plants') comprises assemblages of mosses, liverworts, lichens, bacteria, fungi and other microbes, which typically form a biological crust or skin on the soil surface. This crust not only makes the soil more stable, but also makes it more biologically active. The organism and underlying soil surface form such an intimate bond that they cannot easily be separated without destroying both the organism and underlying soil surface. This unique bond with the soil is what makes biological soil crusts good indicators of the status of the soil surface.

Recent research has indicated that they are not only critical components of healthy landscapes, but are useful indicators of how well we manage our landscapes. Below I describe some recent studies that demonstrate the links between soil crusts and the health of woodland ecosystems.

Semi-arid moss in fruit. Photo: Megan Short

Crusts are good indicators of woodland function

It has long been suspected that crusts would be good indicators of landscape health because of the processes that they control such as infiltration, nutrient buildup and soil stability. A study along 700 km of roadside vegetation within the box woodlands of eastern Australia indicated significant relationships between soil crust richness (number of species from sites with more than 5% crust cover), and an index of landscape function based on measures of tree, shrub, grass and soil health (Cuddy 2000). About 40% of the variation in the measure of landscape function could be explained by the cover of soil crusts.

Studies of crust distribution around watering points in western Queensland have shown that increasing soil health, as measured by the morphology of the soil surface (e.g. degree of cracking, litter accumulation etc), is significantly correlated with increased abundance, richness and diversity of soil crust mosses and liverworts (Tozer and Eldridge unpublished data).

Finally, in a study of 83 White Cypress Pine (*Callitris glaucophylla*) woodland sites across a large area of NSW, increases in diversity and abundance of biological soil crusts corresponded with increasingly more stable surfaces with a greater ability to infiltrate water (Thompson *et al.* in review). These and many other studies (e.g. Eldridge & Koen 1998) confirm that the soil crust organisms can inform us about the health status of landscapes.

Healthy crusts prevent weed incursion

Laboratory-based germination studies have demonstrated that biological soil crusts enhance the germination of some plant species and restrict the germination of others (Eldridge & Simpson 2002). In a study of plant germination on and adjacent to rabbit warrens, the weedy plants Horehound (*Marrubium vulgare*) and Turnip Weed (*Brassica tournefortii*) germinated readily on soil where the crust had been removed but failed to germinate on biologically crusted soils. However, germination of the native perennial grass, Whitetop Grass (*Austrodanthonia caespitosa*) was very high on crusted soils but very low where the crust had been destroyed by rabbits. A stable continuous cover of biological soil crusts was essential to prevent incursion of weeds into woodland soils. Because crusts form an intimate barrier on the soil surface it is understandable that they have an effect on plant germination.

Crusts as indicators of healthy, fertile soils

Over the past 20 years, Australian scientists have pioneered the development of systems designed to characterise ecosystem health in terms of soil surface processes. One of the attributes of the Soil Surface Classification System (Tongway 1995), the cover of biological soil crusts, provides a rapid and reliable assessment of the degree to which the soil cycles nutrients and resists erosion.

Preliminary results from a soil health project in the western Riverina near Griffith indicate that the cover of biological soil crusts and two other surface attributes (soil roughness and litter) can explain up to 62% of the variation in total soil carbon and total soil nitrogen obtained from laboratory studies (Eldridge & Koen unpublished data). In simple terms, this means that simple, quadrat-based measures of biological soil crust cover can provide a 'quick-and-dirty' means of assessing soil health in terms of soil chemistry, allowing large areas of woodland to be assessed relatively quickly and at little cost.

Crustose lichen. Photo: Megan Short

Moss cushion, Little Desert National Park, Victoria. Photo: Megan Short

Soil crusts and disturbance: every patch is important

We studied the soil crust community at 35 sites ranging from cultivated paddocks to large areas of remnant woodland near Savernake in southern NSW. The aim was to examine whether there were links between crust cover and composition, and disturbance. On fine-textured soils, reductions in habitat complexity, remnant area and width, and diversity of vascular plants (all measures of disturbance) were associated with declining biological crust diversity (Eldridge *et al.* in review). Grazing-induced trampling had little effect on crust composition, suggesting to us that either the remaining crust taxa were grazing tolerant, or grazing levels were too low to have an effect. Overall, the results reinforce the view that crusts are important bio-indicators of disturbance in temperate box woodlands.

An important result of the Savernake study was that few sites were species-rich. Rather, many sites contained few species, and few sites contained many species, suggesting to us that in these highly fragmented landscapes many sites are probably required to conserve soil crust species. These issues of conservation of crust species are currently being investigated in other studies.

References

Cuddy, WS. (2000). The distribution and floristics of non-vascular soil crusts in box woodlands on the inland slopes of New South Wales. Unpublished BSc. (Hons.) thesis, University of NSW.

Eldridge, DJ. & Koen, TB. (1998). Cover and floristics of microphytic soil crusts in relation to indices of landscape health. *Plant Ecology* 137: 101-114.

Eldridge, DJ., Freudenberger, D. & Koen, TB. (in review). Diversity and abundance of biological soil crusts in relation to fine- and coarse-scale disturbances in a grassy eucalypt woodland in eastern Australia. *Plant Ecology*.

Thompson, WA., Eldridge, DJ. & Bonser, SP. (in review). Structure of biological soil crust communities in *Callitris glaucophylla* woodlands. *Journal of Vegetation Science*.

Tongway, DJ. (1995). Monitoring soil productive potential. *Environmental Monitoring and Assessment* 37: 303-318.

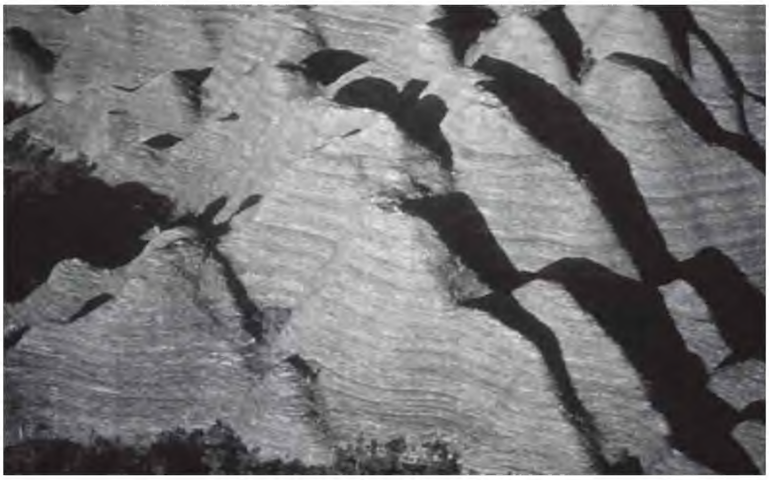
Cyanobacteria: life in environments under stress

Wendy J Williams[1] and Stephen Skinner[2]

[1]University of Queensland Email: wendyjwilliams@bigpond.com

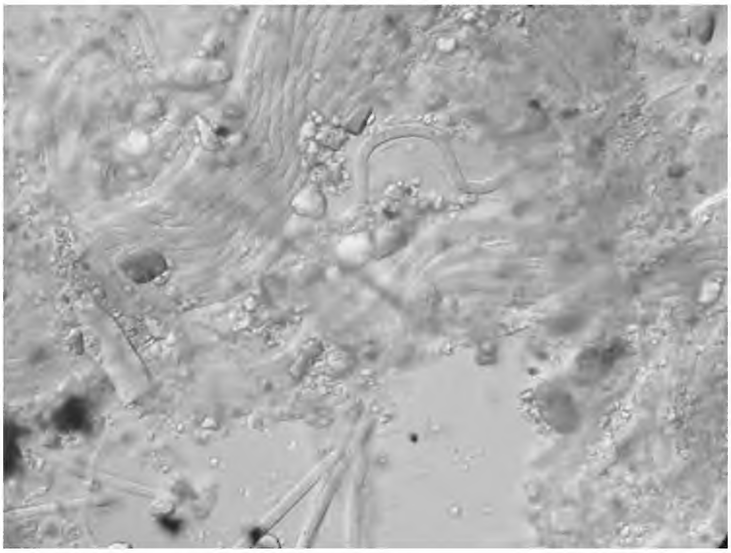
[2]Royal Botanic Gardens, Sydney Email: stephen.skinner@rbgsyd.nsw.gov.au

Cyanobacteria (formerly known as blue-green algae) are microscopic photosynthetic prokaryotes, which occur in habitats so diverse that survival is a key feature of their existence. Adaptation to ecological change within their environment has developed specialist mechanisms allowing them to survive for hundreds of years in microenvironments where other photosynthetic organisms could never exist. In contrast to toxic blooms in waterways, soil and rock inhabiting cyanobacteria almost always have a positive influence on the microenvironment in which they are found. Collectively in the form of cyanobacterial or biological soil crust communities they contribute to arid or semiarid soil surface stability, structure and nutrient pools (Lange *et al*. 1992).



Cyanobacterial crusts (banding effect) dominate the surfaces of sandstone domes in Bungle Bungle Range, Purnululu National Park, WA. Photo: Fiona Lake

Some of the most significant natural geographical features in Australia that are influenced by the presence of cyanobacteria occur in Purnululu National Park (east Kimberley region) and Bald Rock National Park (northern NSW). In Purnululu, throughout the Bungle Bungle Ranges, dark bands formed by cyanobacteria wind horizontally around the magnificent sandstone domes and towers (photo above). These cyanobacterial crusts form a protective skin over the fragile sandstone surfaces helping to stabilise and protect them, yet they almost certainly contribute to the chemical breakdown of the rock. (Hoatson *et al*. 1997). Bald Rock, the largest granite-like rock dome in Australia has a water



Micrograph of filamentous cyanobacterium Trichocoleus sociatus *(4 µm width) entwined with fine particles of sand. Photo: W. Williams*

streaked surface, and over time has created a zonation of cyanobacteria and lichens according to their preferred environmental niche. Cyanobacterial colonies such as these commonly occur on boulders and rocky outcrops, and have recently been found to actively fix nitrogen. The nitrogen is retained under their surface 'skin' and released during rain events, when it is washed from the rock faces into the surrounding soil environment (pers. comm. B. Büdel). It is thought that this feature of rock inhabiting cyanobacteria has been an important influence on the development and composition of surrounding vegetation.

Cyanobacterial soil crusts

Cyanobacteria occur as single cells, filaments or colonies (photo above). Often cyanobacteria will form a thick crust on the soil surface. These biological crusts are sometimes solely composed of cyanobacteria (commonly e.g. *Nostoc commune*) or dominated by cyanobacteria (co-existing with other cryptogams) and in this case are called cyanobacterial soil crusts (photo right). Crusts often are commonly found in harsh arid environments, where soil type, microenvironments and pH are key influences in species composition (Eldridge & Tozer, 1997). Within the crust environ many cyanobacteria have sticky mucilaginous sheaths that bind soil particles together and thus provide stability. These sheaths also contain pigments that protect against harmful UV rays and, along with other special cell structures, assist survival during long periods of desiccation (Wynn-Williams, 2000).

Trampling by domestic stock, vehicular traffic and even repeated walking on cyanobacterial soil crusts are generally regarded as having a negative influence on survival and biodiversity of crust organisms (Belnap & Eldridge, 2003; Warren & Eldridge, 2003). However, as with all land management, it is possible to effect practices that minimise damage. During drought cyanobacteria and other crust organisms are brittle and fragile and become extremely susceptible to damage by disturbance. It is not surprising that de-stocking during drought greatly influences the recovery phases of the cyanobacterial soil crusts and assists the nitrogen build up in the soil during drought (Williams, unpublished data).

Cyanobacteria contribute to low nutrient soils

In arid regions where nutrients are low cyanobacteria are known to contribute both carbon and nitrogen to the soil nutrient pool (Lange *et al.*, 1992; Evans & Lange, 2003). Many species of cyanobacteria contain heterocysts, specialist cells that fix atmospheric nitrogen. During drought cyanobacterial crusts are often covered by thin layers of dust or sand, however 'nuisance rain' or dews enable the cyanobacteria to continue to fix nitrogen. With the presence of moisture the cyanobacterial filaments are still capable of travelling to the surface to 'harvest' light, then retreat into their protective sheaths below the soil surface and fix nitrogen in the dark (Belnap, 2003). This pool of nitrogen seems to remain trapped within the first centimetre of soil (Williams, unpublished data) until used by germinating plants for a flush of growth after significant rain. This process appears to be a crucial part of the arid soil nutrient cycle, aiding recovery after drought or disturbance.

Nostoc commune *develops a thick gelatinous crust rich in available nitrogen. Photo: W. Williams*

Biodiversity and conservation of terrestrial cyanobacteria in Australia

Skinner and Entwistle (2001a,b) have described some non-marine cyanobacteria, however almost all terrestrial cyanobacteria within Australia still remain undescribed. It is believed that many taxa are aligned with European species, although the distribution of individual species could be associated with countries historically linked to Gondwana (pers. comm. B. Büdel). Over time cyanobacteria develop morphological features that are unique to their environment, so species separation can become complex and may only be possible through DNA analysis combined with taxonomic descriptions.

Some research into biological and cyanobacterial soil crusts has incorporated cyanobacteria, although rarely at a genus or species level due to lack of expertise or reliable records of taxa. Nevertheless, cyanobacteria are an important living component of soil environment and of biodiversity in arid landscapes. The extent of the contribution by these tiny organisms is just becoming known, and continuing research is needed to expand our knowledge of their diversity, ecology and role in the environment.

References

Belnap, J. (2003). Nitrogen fixation in biological soil crusts. In: J. Belnap & OL. Lange (Eds). *Biological Soil Crusts: Structure, Management and Function.* Ecological Studies 150, Springer Verlag, Berlin.

Belnap, J. & Eldridge, DJ. (2003). Disturbance and recovery of biological soil crusts. In: J. Belnap & OL. Lange (Eds). *Biological Soil Crusts: Structure, Management and Function.* Ecological Studies 150, Springer Verlag, Berlin.

Evans, RD. & Lange, OL. (2003). Soil crusts, nitrogen and carbon dynamics. In: J. Belnap & OL. Lange (Eds). *Biological Soil Crusts: Structure, Management and Function.* Ecological Studies 150, Springer Verlag, Berlin.

Eldridge, DJ. & Tozer, ME. (1997). Environmental factors relating to the distribution of terricolous bryophytes and lichens in semi-arid eastern Australia. *The Bryologist* 100: 28-39.

Hoatson, D., Blake, D., Mory, A., Tyler, I., Pittavino, M., Allen, B. & Kamprad, J. (1997). *Bungle Bungle Ranges, Purnululu National Park, East Kimberley, Western Australia: a guide to rocks, landforms, plants, animals and human impact.* Australian Government Publishing Service, Canberra.

Lange, OL., Kidron, GJ., Büdel, B., Meyer, A., Kilian, E. & Abelovich, A. (1992). Taxonomic composition and photosynthetic characteristics of the "biological crusts" covering sand dunes in the western Negev Desert. *Functional Ecology* 6: 519–527.

Skinner, S. & Entwisle, TJ. (2001a). Non-Marine algae of Australia: 1. Survey of colonial gelatinous blue-green macroalgae (Cyanobacteria). *Telopea* 9: 573–599.

Skinner, S. & Entwisle, TJ. (2001b). Non-Marine algae of Australia: 2. Some conspicuous tuft-forming Cyanobacteria. *Telopea* 9: 685–712.

Warren, SD. & Eldridge, DJ. (2003). Biological soil crusts and livestock. In: J. Belnap & OL. Lange (Eds). *Biological Soil Crusts: Structure, Management and Function.* Ecological Studies 150, Springer Verlag, Berlin.

Wynn-Williams, DD. (2000). Cyanobacteria in deserts. In: BA. Whitton and M. Potts (Eds). *The ecology of cyanobacteria – their diversity in time and space*. Kluwer Academic Publishers, The Netherlands.

Resource Kit Review

Forgotten Flora

Resource Kit 2004 [3 CD-R & 10 posters], Royal Botanic Gardens Melbourne, Australia ISBN 0 9751362 4 0. Price $154.00. To order: http://www.rbg.vic.gov.au/research_and_conservation/publications/forgotten_flora

Anyone with a passion to introduce young or older minds to the hugely important 'underdogs' of our biota – the bryophytes, fungi, and lichens – will welcome publication of this new resource package. Combining the expertise of bryologist Josephine Milne, mycologist Teresa Lebel, illustrator Anneke Veenstra-Quah, and educator Gary Shadforth, the package of CDs and posters provides a superb educational resource. Separate CDs cover the bryophytes, (non-lichenised) fungi and the lichens, each beginning with a comparable introduction to the Forgotten Flora project.

The CDs are aimed mainly at teachers, pitched at an appropriate level to include those who lack formal training in botany and mycology. The CDs provide the important background information about each group of organisms, accompanied by colour illustrations and full explanations of terms used. There is a short page on the relationship of each CD's contents to the Key Learning Areas of the Curriculum and Standards Framework for Biological Science and for VCE Biology. Along with a well explained and tested set of Activities for students, the CDs equip the teacher with a comprehensive resource kit for motivating and educating students about these organisms. I judge that the kits are aimed at teachers of students in the 10 to 17-year-old age group.

In structure, each CD is similar to a book. For example, the Bryophyte CD contains 80 'pages', most pages comprising two screens. Pages may be printed out for distribution to students, and the pdf version simplifies this process. A narrow window on the left hand side of the screen provides an outline of the contents, each item hyperlinked to the relevant section. However, there is opportunity for more electronic linkage, for example indicating to the user that the next page includes additional relevant information. Scrolling through the pdf version is a relatively simple way to view the scope and content of the CD, and also shows the abundance of high quality colour and line drawing illustrations.

Each CD includes a range of Activities for students, plus suggestions for Research Ideas. Examples among the 15 Activities in the Fungi CD are "Making a spore print" and "Unique substrates. The Bull's-eye fungus or Physics and Fungi". Each Activity and Worksheet section begins with a series of "Fascinating Facts" to whet the teacher's appetite. Each Activity includes a full explanation of methods as well as helpful photographs to ensure that even teachers new to biology can prepare the desired materials. There is also a 'word-find' activity in each CD and a crossword in the Bryophyte CD.

The Resources and Links section provides a list of story books (details rather sketchy for some), general books on fungi, and field guides (reference simply to "Fungimap book" might restrict access for the uninitiated user, although the Fungimap web site is listed on the same page). The list of web sites and suggested locations for field work in Victoria are further relevant features. If future editions of these CDs are planned, expanded coverage to include other states of Australia and also New Zealand should be considered.

The 10 high quality posters, each 900 x 600 mm, make a wonderfully colourful and instructive display for classroom, library, and children's bedroom, and are also suitable for public display in government agencies, universities and outdoor venues. They are organised around questions and themes such as "Where does the *Forgotten Flora* grow?", "Taking a liking to Lichens", "Miniature forests and carpets", as well as including interactions with associated organisms such as the poster entitled "What lives amongst the *Forgotten Flora?"*. Each poster is visually attractive, with colour photographs and clearly presented text. I had my set of posters promptly laminated as they will be well used. Although the posters are focused on an Australian audience, they are also applicable to other regions, there being a dearth of such well presented introductory material in poster form.

Final production of the CDs may have been somewhat rushed as suggested by the minimal use of hyperlinks, a few typographical errors, occasional omission of reference citations, and an awkward flow between pages in the CD. The posters appear to have received more attention editorially and graphically. Indeed the poster titles have been modified somewhat from those cited in each CD. Nevertheless, the foundation for a valuable and effective teaching resource has been laid, and further editions can only improve both the ease of use and applicability of this resource to a wider geographic area.

The authors' passion for their subject is obvious in the content of this resource kit. In their words, "A fascinating, weird and beautiful world awaits in the small forests and carpets of the *Forgotten Flora*." They have made this world much more accessible to all teachers who use this resource, and in so doing have made a major contribution to their stated aim "to promote increased awareness of the *Forgotten Flora*, their importance to the environment, and their beauty". I recommend both CDs and posters to all middle and senior school science and biology teachers, and the posters to anyone who wants to publicise the bryophytes, fungi, and lichens or to simply enjoy the beauty and intriguing morphological variation of these diverse organisms.

Peter Buchanan
Team Leader, Biosystematics, Landcare Research,
Auckland, New Zealand

Research Roundup

Claridge, AW. & Trappe, JM. (2004). **Managing habitat for mycophagous (fungus-feeding) mammals: a burning issue?** In: D. Lunney (Ed.). *Conservation of Australia's forest fauna*, 2nd edn, pp. 936-946. Royal Zoological Society of New South Wales, Mosman.

Fenton, NJ. & Frego, KA. (2005). **Bryophyte (moss and liverwort) conservation under remnant canopy in managed forests**. *Biological Conservation* 122: 417-430.

Hallingbäck, T. (2004). **World-wide status of bryophyte conservation - results from a questionnaire**. *Bryological Times* 113: 4-7.

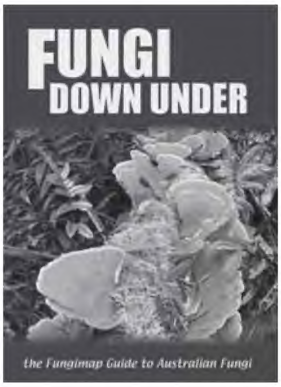
Kantvilas, G. (2004). ***Cladonia tasmanica* - an extinct lichen.** *Australasian Lichenologist* 54: 8-13.

Morgan, JW. (2004). **Bryophyte composition in a native grassland community subjected to different long-term fire regimes.** *Cunninghamiana* 8: 485-489.

Turner, PAM. & Pharo, EJ. (2005). **Influence of Substrate Type and Forest Age on Bryophyte Species Distribution in Tasmanian Mixed Forest.** *The Bryologist* 108: 67-85.

Information Resources and Useful Websites

Fungi Down Under: the Fungimap Guide to Australian Fungi



Pat Grey & Ed Grey, 2005,
Fungimap

A richly illustrated guide to the 100 target species of the Fungimap scheme. The first field guide to Australian fungi to include maps of all species. ISBN: 0-646-44674-6. $29.95. Available online from Fungimap at http://www.rbg.vic.gov.au/fungimap_/fungi_down_under.

Resources for the 'forgotten flora'

An extensive list of publications and websites relevant to the conservation of non-vascular plants and fungi. Provided on the website of the Botanic Gardens Trust, Sydney. Go to: http://www.rbgsyd.nsw.gov.au/conservation_research/plant_conservation/conservation_of_nonvascular_plants_and_fungi

Fungi Conservation Case Study

A case study on fungi conservation in Lane Cove Bushland Park. Part of the Introduction to Fungal Biology course developed by the School of Biological Sciences, University of Sydney. Go to: http://bugs.bio.usyd.edu.au/Mycology/Ecology/conservation.shtml

IUCN SSC Bryophyte Specialist Group

Includes the 2000 IUCN World Red List of Bryophytes, and fact-sheets for globally red-listed bryophyte species. This actively maintained website also has a 'what's new' section, which currently provides a summary of a recent successful workshop on the first official red list of endangered Chinese bryophytes. Go to: http://www.artdata.slu.se/guest/SSCBryo/SSCBryo.html.

Survey Guidelines for Non-vascular Plants

D. Eldridge, S. Skinner & T.J. Entwisle

Botanic Gardens Trust Sydney, 2003

This manual will assist with the inclusion of cryptogams in routine vegetation surveys. A variety of methodologies are presented, at a range of levels from species to morphological groups. Download from http://www.nationalparks.nsw.gov.au/PDFs/Survey_Guide_Non-Vascular_Plants.pdf

A Conservation Overview of Australian Non-marine Lichens, Bryophytes, Algae and Fungi

G.A.M. Scott, T.J. Entwisle, T.W. May & G.N. Stevens
Environment Australia

Although published in 1997, this document remains the most up-to-date summary of the conservation status of Australian cryptogams. Includes extensive appendices on endangered cryptogams and their critical habitat. Printed copies are hard to obtain, so it is useful to be aware of the web version. See http://www.deh.gov.au/biodiversity/threatened/action/cryptogams/

Cubberla-Witton Catchments Network. Fungi Information.

An example of the inclusion of information about fungi on the website of a catchment management body. Covers different groups of fungi such as agarics and polypores.

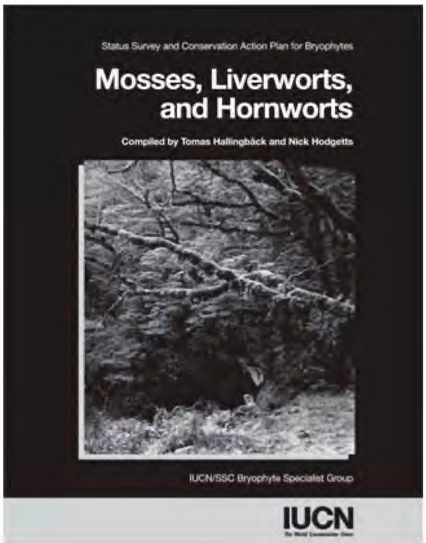
Go to: http://www.cubberlawitton.org/fungi

Mosses, Liverworts, and Hornworts. Status Survey and Conservation Action Plan for Bryophytes

T. Hallingbäck & N. Hodgetts

IUCN/SSC Bryophyte Specialist Group, 2000

This global conservation action plan for bryophytes contains sections on the importance of bryophytes and threats to them, along with regional overviews of conservation status, including for Australasia. Download from http://www.iucn.org/themes/ssc/actionplans/bryophytes/contents.pdf


Status Survey and Conservation Action Plan for Bryophytes
Mosses, Liverworts, and Hornworts
Compiled by Tomas Hallingbäck and Nick Hodgetts
IUCN/SSC Bryophyte Specialist Group
IUCN

ANPC Workshops

Workshops on the management and rehabilitation of disturbed native vegetation

14-15 September, Wagga Wagga, NSW.

25-26 October, Dubbo, NSW

These two workshops are the last of three workshops on native vegetation rehabilitation to be held in regional NSW this year. The first, held in Armidale in July, was an overwhelming success and registrations had to close after over 100 registrations were received. **So you better be quick to register!**

Workshop focus: The knowledge and skills required to undertake ecological rehabilitation and management of disturbed native vegetation.

The workshop will be of interest to anyone involved in native vegetation rehabilitation and management; eg: local Councils, State government agencies, utilities providers (eg power, water), managers of stock reserves, road or rail easements, NRM/biodiversity staff, CMA staff, industry, environmental consultants, Landcare and other community groups, private landholders and other land managers and decision makers.

Themes include:

- NSW vegetation legislation essential for rehabilitation practitioners & projects.
- The ecological principles essential to planning a rehabilitation project.
- Applying the principles to actual rehabilitation projects (case studies, workshop activity, site visits, techniques).
- Understanding the task (the goal for the site, planning, consultation needed, issues such as conservation genetics, provenance, the role of soil symbionts, monitoring and ongoing management).

Further information on these workshops is available on www.anbg.gov.au/anpc (click on "TRAINING").

Environmental
TRUST

Workshops on the translocation of threatened plants

Tue 30th August, Coffs Harbour, NSW

Sat 1st October 2005, Adelaide, SA (during ANPC Conference)

This highly successful workshop has now been held eight times across Australia. The workshop is aimed at anyone involved in the planning, approval or implementation of translocation projects for threatened flora. Participants in the course will not only gain substantial knowledge on the day but will also receive a copy of the *Guidelines for the Translocation of Threatened Plants.* Programs and registration forms for the Coffs Harbour workshop are available at on www.anbg.gov.au/anpc (click on "TRAINING") and for the Adelaide workshop are available via the conference website: www.plevin.com.au/ANPC2005.

Grass Identification Techniques

Thur 27th October, Dubbo, NSW.

This workshop follows the 2-day workshop at the same venue on the rehabilitation and management of disturbed native vegetation (see left).

Participants will learn to use a variety of tools available for identifying native and exotic grasses, using available field guides and the interactive CD-ROM 'AusGrass - Grasses of Australia'. The workshop will be of value to anyone keen on identifying native and exotic grasses. This includes interested individuals as well as anyone involved in native vegetation rehabilitation and management, such as local Councils, government agencies, utilities providers (eg power and water), managers of stock reserves, road and rail easements, NRM/biodiversity staff, CMA staff, industry, environmental consultants, Landcare and other community groups, private landholders or other land managers as well as ecology and botany students. Workshop presenters and guides will be skilled in grass identification techniques. Additional information and registration form will be available from the ANPC website shortly (www.anbg.gov.au/anpc).

Conservation Techniques Workshops

Friday 30th September, Adelaide, SA

These workshops will be held during the ANPC Conference in September (you can register for the workshops and not the conference and vice versa). We have gathered together a fine collection of topics supported and presented by an even finer group of your colleagues. Each workshop runs for 1½ hours and workshop topics include:

- comparison and analysis of techniques for assessing vegetation
- developing incentives for conservation on private land
- fire ecology and the impact of fire regimes on plant diversity
- establishing seed orchards for plant conservation: principles and practices
- developing effective communication strategies for plant conservation
- interactive media for plant identification.
- sampling designs, field techniques and analytical methods for systematic plant population surveys
- indigenous plants and people
- urban ecology - managing small patches

Additional information and registration form available via the conference website: www.plevin.com.au/ANPC2005

Conferences and Workshops

NZ Plant Conservation Network Conference 2005: 'Restoring our threatened plant life – empowering our community'.

12-14 August, Christchurch, NZ

This will be an exciting event for anyone interested in protecting, growing or studying New Zealand's native plants. The conference will include a series of plant conservation workshops on subjects such as: threatened plant propagation, cultural use of native plants and fungi, how to implement the Global Strategy for Plant Conservation by 2010, enhancing plant diversity in the urban environment, developing a national *ex situ* strategy for threatened plants, and introduction to threatened and common fungi. For further details see: http://www.nzpcn.org.nz

National Conference of the Australian Network for Plant Conservation: Plant Conservation; The challenges of Change

26 September – 1 October, Adelaide, South Australia

The ANPC and the South Australian Department of Environment and Heritage invite you to Adelaide to exchange ideas and to participate in discussions on the challenges that currently face us all in plant conservation. Whether these be challenges of changing climates, changing environmental conditions, changes in government and policy focus, or confronting scientific information, this conference will stimulate consideration and participation. Conference sub-themes include: 1. Extreme Policy Changes, 2. Urban Ecology, 3. Using Revegetation to Achieve Ecological Outcomes, and 4. Indigenous Interests in Conservation. The conference will appeal to all those involved in plant conservation from the on-ground practitioners to researchers and policy makers. All are invited to share experiences in managing for conservation in times of change and uncertainty. For additional information go to www.pelvin.com.au/ANPC2005. See also notes on the conference workshops under 'ANPC workshops'.

Weedbuster Week

8th - 15th October 2005

Detailed information of organised events for the week can be located via local Local Council weed officers or on the weedbuster website http://www.weedbusterweek.info.au/.

Flora Conservation Symposium "Advances in Plant Conservation Biology: Implications for Flora Management and Restoration"

Perth, Western Australia, 25th - 27th of October 2005.

This symposium will include a number of international, national and local speakers with expertise covering a range of key issues in plant conservation biology. The symposium will highlight recent advances in plant conservation biology and their significance in the management and restoration of plant species and communities. For further information see attachment or contact David Coates or Leonie Monks via email on floras@calm.wa.gov.au

Growing Wetlands Workshop: Advances in wetland conservation and restoration

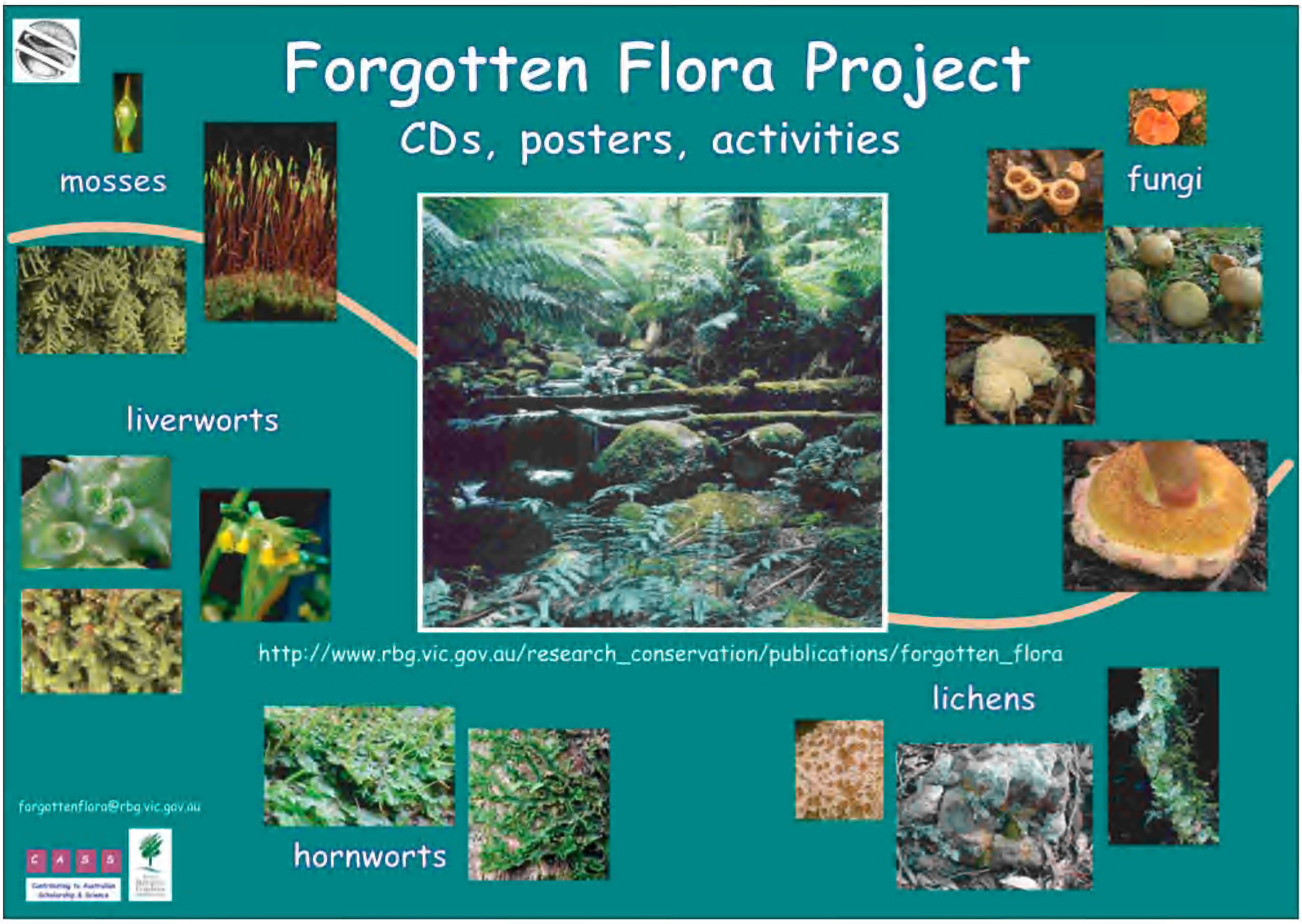
7-9 November, 2005, Perth, Western Australia.

This workshop aims to increase understanding of current global 'best practice' in wetland conservation, restoration and management. Registration and payment is required by 30th August 2005. Contact: Deanna Rokich or Kingsley Dixon, Botanic Gardens and Parks Authority, Kings Park and Botanic Garden, Western Australia. Email: drokich@bgpa.wa.gov.au, Phone: (08) 9480 3623, Fax: (08) 9480 3641.

Eighth International Mycological Congress

20 – 26 August 2006, Cairns, Queensland

Will be the first International Mycological Congress held in the Southern Hemisphere. You can register interest online at http://www.sapmea.asn.au/conventions/imc8/index.html



Forgotten Flora Project

CDs, posters, activities

http://www.rbg.vic.gov.au/research_conservation/publications/forgotten_flora

forgottenflora@rbg.vic.gov.au

ANPC Major Sponsors

GOLD SPONSORS

Australian National
Botanic Gardens, ACT

OTHER SPONSORS

TransGrid

Centre
for Plant
Biodiversity
Research

Botanic Gardens
of ADELAIDE

Environmental
TRUST

Royal
Botanic
Gardens
Melbourne

Government
of South Australia

Department
for Environment
and Heritage

Australian Network for Plant Conservation

presents two workshops at

Western Plains Zoo, Dubbo, NSW

Rehabilitation and management of disturbed native vegetation workshop

25-26 October 2005

Are you involved in the rehabilitation of native vegetation? Does your work-site include native vegetation that you need to manage or rehabilitate? Do you participate in local rehabilitation projects? Are you interested in reversing the decline of native plant communities in your area? Then this workshop is for you!

Workshop focus:

- The knowledge and skills to undertake ecological rehabilitation and management of disturbed native vegetation.

Themes include:

- NSW vegetation legislation essential for rehabilitation practitioners and projects.
- The ecological principles essential to planning a rehabilitation project.
- Applying the principles to actual rehabilitation projects (case studies, workshop activity, site visits, techniques).
- Understanding the task (assessing site condition, the goal for the site, planning, issues such as conservation genetics, provenance, soil-symbionts, monitoring and ongoing management).

The workshop will be a mix of presentations by experienced rehabilitation practitioners and visits to selected field sites. Participants will expand their skills and knowledge, challenge preconceptions, exchange ideas and expertise, work with experts and broaden networks.

Workshop fees (incl catering, field trip, Plant Conservation Techniques manual on CD & GST):

ANPC member: $165	***Concession: $75**
Non-member: $185	***Concession: $95**

* Concession for volunteer community group members, full-time students, pensioners.

Grass identification techniques course

27 October 2005

Learn how to identify native and exotic grasses using grass keys and the interactive CD-ROM *AusGrass - Grasses of Australia*. Tutors will be skilled in grass identification techniques.

Course fee (includes morning & afternoon tea & lunch + GST):

ANPC member: $95	***Concession: $65**
Non-member: $115	***Concession: $75**

* Concession for volunteer community group members, full-time students, pensioners.

Registrations close for both workshops: 14 October 2005. Get in quick!

Accreditation: Participation in ANPC workshops and courses can now contribute to qualifications in the Conservation and Land Management Training Package. Cost = $25 (incl GST). More information available on request (and on ANPC website).

Environmental TRUST

Photos (top to bottom): Billy buttons in native grassland near Forbes. Photo: Lucy Butterfield, Central West CMA; Ian Davidson and Tracy Michael assessing a site for rehabilitation; *Bursaria spinosa* at a rehabilitation site. Photos: Paul Scannell; Local landholders enjoying a field day near Grenfell. Photo: Lucy Butterfield, Central West CMA; *Hardenbergia violacea* on white box trunk in a rehabilitation site. Photo: Paul Scannell; Supplementary tubestock planting in a remnant Grey Box community near Parkes; Variety of revegetation seeds including *Acacia* and *Dodonaea* species. Photos: Lucy Butterfield, Central West CMA

Australasian Plant Conservation

BULLETIN OF THE AUSTRALIAN NETWORK FOR PLANT CONSERVATION

For further information contact:
Australian Network for Plant Conservation
GPO Box 1777
Canberra ACT 2601, Australia

Ph: + 61 2 6250 9509
Fax: + 61 2 6250 9528
Email: anpc@deh.gov.au
Website: http://www.anbg.gov.au/anpc